

Introduction to SQL

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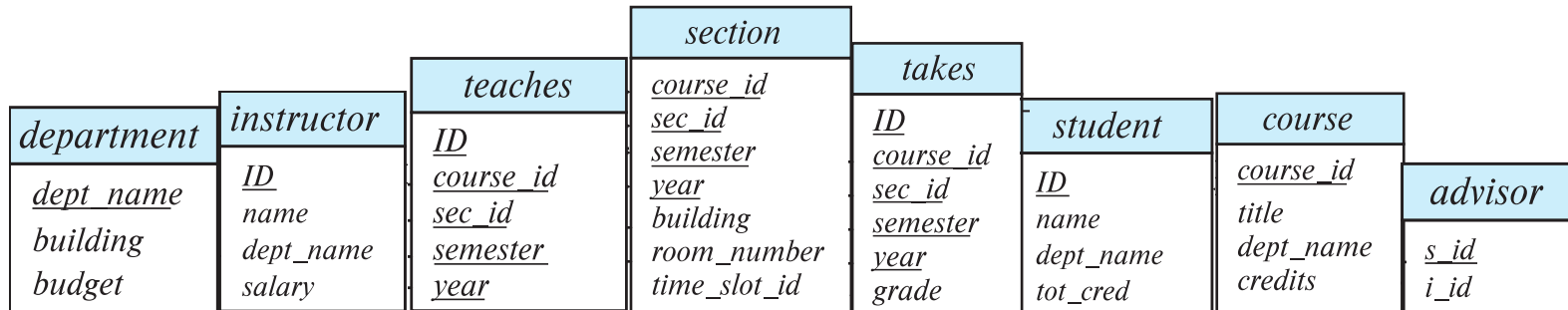
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Basic Query Structure

- A typical SQL query has the form:

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



Basic Query Structure (demo)

1. Find the names of all instructors
2. Find the department names of all instructors, and remove duplicates
3. Find the department names of all instructors, not removing duplicates
4. Find all attributes of instructor show the entire instructor table
5. Find a relation that is the same as the *instructor* relation, except that the value of the attribute *salary* is divided by 12
6. Find all instructors in Comp. Sci. dept with salary > 70000
7. Find the names of all instructors who have taught some course and the course_id
8. Find the names of all instructors in the Comp. Sci. department who have taught some course and the course_id
9. Find the names of all instructors who have a higher salary than some instructor in 'Comp. Sci'.

		<i>teaches</i>		<i>section</i>	<i>takes</i>		<i>course</i>	<i>advisor</i>
<i>department</i>	<i>instructor</i>	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	
<u>dept_name</u>	<u>ID</u>	<u>course_id</u>	<u>sec_id</u>	<u>sec_id</u>	<u>course_id</u>	<u>sec_id</u>	<u>title</u>	<u>s_id</u>
<i>building</i>	<i>name</i>	<u>semester</u>	<i>year</i>	<i>semester</i>	<i>year</i>	<i>year</i>	<i>dept_name</i>	<i>i_id</i>
<i>budget</i>	<i>dept_name</i>	<i>year</i>	<i>building</i>	<i>room_number</i>	<i>grade</i>	<i>tot_cred</i>	<i>credits</i>	
	<i>salary</i>		<i>time_slot_id</i>					

Basic Query Structure (demo)

- Find the names of all instructors whose name includes the substring “in”.
- String Operations
 - 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 has 4 characters.
- Find the names of all instructors whose name has at least 4 characters.

				section				
department	instructor	teaches			takes	student	course	
<u>dept_name</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	
building	name	<u>sec_id</u>	<u>semester</u>	<u>sec_id</u>	<u>course_id</u>	name	title	advisor
	dept_name	<u>year</u>	<u>building</u>	<u>year</u>	<u>sec_id</u>	dept_name	dept_name	<u>s_id</u>
	salary	<u>year</u>	<u>room_number</u>	<u>time_slot_id</u>	<u>semester</u>	tot_cred	credits	<u>i_id</u>
					<u>year</u>			
					grade			

Basic Query Structure (demo)

1. List in alphabetic order the names of all instructors
2. List in descending alphabetic order the names of all instructors
3. List in order of the combination of the names and salary of all instructors
4. Find the names of all instructors with salary between \$90,000 and \$100,000
5. Find courses that ran in Fall 2017 or in Spring 2018
6. Find courses that ran in Fall 2017 and in Spring 2018
7. Find courses that ran in Fall 2017 but not in Spring 2018
8. Find courses that ran in Fall 2017 or in Spring 2018, retain all duplications
9. Find all instructors whose salary is null
10. Find all instructors whose salary is not null
11. Null under and, or, with true/false

		<i>teaches</i>		<i>section</i>	<i>takes</i>		<i>course</i>	<i>advisor</i>
<i>department</i>	<i>instructor</i>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<u><i>course_id</i></u>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<u><i>course_id</i></u>	
<u><i>dept_name</i></u>	<u><i>ID</i></u>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>course_id</i>	<i>sec_id</i>	<i>title</i>	<u><i>s_id</i></u>
<i>building</i>	<i>name</i>	<i>sec_id</i>	<i>year</i>	<i>building</i>	<i>sec_id</i>	<i>semester</i>	<i>dept_name</i>	<i>i_id</i>
<i>budget</i>	<i>dept_name</i>	<i>semester</i>	<i>room_number</i>	<i>room_number</i>	<i>year</i>	<i>grade</i>	<i>credits</i>	
	<i>salary</i>	<i>year</i>	<i>time_slot_id</i>	<i>time_slot_id</i>				

Basic Query Structure (demo)

- 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

select A_1, A_2, \dots, A_n  Aggregation function over values over multiple rows

from r_1, r_2, \dots, r_m

where P

group by columns  New clauses

having condition 

department		instructor		teaches	section	takes	student	course	advisor
<u>dept_name</u>	<u>ID</u>	<u>ID</u>	<u>name</u>	<u>ID</u>	<u>course_id</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	
building	dept_name	name	dept_name	course_id	sec_id	course_id	name	title	s_id
budget	salary	sec_id		semester	year	sec_id	dept_name	dept_name	i_id
		year		building	room_number	semester	tot_cred	credits	
				time_slot_id		year			
						grade			

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

Aggregate – Group By - Having

1. Find the average salary of instructors in each department
2. Find the names and average salaries of all departments whose average salary is greater than 42000
3. Find the names and average salaries of all departments over instructors whose salary is greater than 70000
4. Find the names and average salaries of all departments whose average salary is greater than 70000
5. Find the average salaries of instructors who have taught a course

				section				
department	instructor	teaches			takes	student	course	
<u>dept_name</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	<u>advisor</u>
building	name	<u>sec_id</u>	<u>sec_id</u>	<u>sec_id</u>	<u>course_id</u>	name	title	<u>s_id</u>
budget	dept_name	<u>semester</u>	<u>semester</u>	<u>year</u>	<u>sec_id</u>	dept_name	dept_name	<u>i_id</u>
	salary	<u>year</u>	<u>year</u>	<u>building</u>	<u>semester</u>	tot_cred	credits	
				<u>room_number</u>	<u>year</u>			
				<u>time_slot_id</u>	<u>grade</u>			

Nested 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 A1, A2, ..., An
from r1, r2, ..., rm
where P
```

as follows:

- **From clause:** r_i can be replaced by any valid subquery
- **Where clause:** P can be replaced with an expression of the form:

$B <\text{operation}> (\text{subquery})$

B is an attribute and $<\text{operation}>$ to be defined later.

- **Select clause:**

A_i can be replaced by a subquery that generates a single value.

		teaches		section	takes		course	advisor
department	instructor	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u>	<u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> <u>building</u> <u>room_number</u> <u>time_slot_id</u>		<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> <u>grade</u>	<u>ID</u> <u>name</u> <u>dept_name</u> <u>tot_cred</u>	<u>course_id</u> <u>title</u> <u>dept_name</u> <u>credits</u>	
<u>dept_name</u> building budget	<u>ID</u> name dept_name salary							<u>s_id</u> <u>i_id</u>

Subquery in Where Clause

1. Name all instructors whose name is either “Mozart” or Einstein”
2. Name all instructors whose name is neither “Mozart” nor Einstein”
3. Find the total number of (distinct) students who have taken course sections taught by the instructor with *ID* 10101 or 12121 or 15151
4. Find names of instructors with salary greater than that of some (at least one) instructor in the Computer Science department.
5. Find all instructors earning the highest salary (there may be more than one with the same salary).
6. Find the names of all instructors whose salary is greater than the salary of all instructors in the Biology department.

		<i>teaches</i>		<i>section</i>	<i>takes</i>		<i>student</i>	<i>course</i>	<i>advisor</i>
<i>department</i>	<i>instructor</i>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<u><i>sec_id</i></u>	<u><i>course_id</i></u>	<u><i>sec_id</i></u>	<u><i>ID</i></u>	<u><i>course_id</i></u>	
<u><i>dept_name</i></u>	<i>ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>course_id</i>	<i>sec_id</i>	<i>name</i>	<i>title</i>	<u><i>s_id</i></u>
<i>building</i>	<i>dept_name</i>	<i>semester</i>	<i>year</i>	<i>building</i>	<i>semester</i>	<i>year</i>	<i>dept_name</i>	<i>dept_name</i>	<i>i_id</i>
<i>budget</i>	<i>salary</i>	<i>year</i>	<i>time_slot_id</i>	<i>room_number</i>	<i>grade</i>	<i>tot_cred</i>		<i>credits</i>	

Definition of “some” Clause

- $F <\text{comp}> \text{some } r \Leftrightarrow \exists t \in r \text{ such that } (F <\text{comp}> t)$

Where $<\text{comp}>$ can be: $<$, \leq , $>$, $=$, \neq

$(5 < \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline 6 \\ \hline \end{array}) = \text{true}$ (read: $5 <$ some tuple in the relation)

$(5 < \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline \end{array}) = \text{false}$

$(5 = \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline \end{array}) = \text{true}$

$(5 \neq \text{some } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline \end{array}) = \text{true (since } 0 \neq 5)$

$(= \text{some}) \equiv \text{in}$

However, $(\neq \text{some}) \not\equiv \text{not in}$

Definition of “all” Clause

- $F \text{ <comp> all } r \Leftrightarrow \forall t \in r (F \text{ <comp> } t)$

$$(5 < \text{all } \begin{array}{|c|} \hline 0 \\ \hline 5 \\ \hline 6 \\ \hline \end{array}) = \text{false}$$

$$(5 < \text{all } \begin{array}{|c|} \hline 6 \\ \hline 10 \\ \hline \end{array}) = \text{true}$$

$$(5 = \text{all } \begin{array}{|c|} \hline 4 \\ \hline 5 \\ \hline \end{array}) = \text{false}$$

$$(5 \neq \text{all } \begin{array}{|c|} \hline 4 \\ \hline 6 \\ \hline \end{array}) = \text{true (since } 5 \neq 4 \text{ and } 5 \neq 6)$$

$(\neq \text{all}) \equiv \text{not in}$

However, $(= \text{all}) \not\equiv \text{in}$

Subquery in Where Clause

- The **exists** construct returns the value **true** if the argument subquery is nonempty.
 - Find all courses taught in both the Fall 2017 semester and in the Spring 2018 semester
- 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 2017

				section				
department	instructor	teaches			takes	student	course	advisor
<u>dept_name</u> building budget	<u>ID</u> name dept_name salary	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u>		<u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> building room_number time_slot_id	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> grade	<u>ID</u> name dept_name tot_cred	<u>course_id</u> title dept_name credits	<u>s_id</u> <u>i_id</u>

Query Quest

1. Find names of instructors with salary greater than that of some (at least one) instructor in the Computer Science department.
 - Use self-join, some, exists, aggregation
2. Find all instructors earning the highest salary (there may be more than one with the same salary).
 - Use self-join, all, exists, aggregation

				section				
department	instructor	teaches			takes	student	course	
<u>dept_name</u> building budget	<u>ID</u> name dept_name salary	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u>		<u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> building room_number time_slot_id	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> grade	<u>ID</u> name dept_name tot_cred	<u>course_id</u> title dept_name credits	advisor
								<u>s_id</u> <u>i_id</u>

Subquery in From and Select Clauses

1. Find the average instructors' salaries of those departments where the average salary is greater than \$42,000"
2. Find all departments with the maximum budget (with clause)
3. Find all departments where the total salary is greater than the average of the total salary at all departments
4. List all departments along with the number of instructors in each department

				section				
department	instructor	teaches			takes	student	course	
<u>dept_name</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	<u>advisor</u>
building	name	<u>sec_id</u>	<u>sec_id</u>	<u>sec_id</u>	<u>course_id</u>	name	title	<u>s_id</u>
budget	dept_name	<u>semester</u>	<u>semester</u>	building	<u>sec_id</u>	dept_name	dept_name	<u>i_id</u>
	salary	<u>year</u>	<u>year</u>	room_number	<u>semester</u>	tot_cred	credits	
				time_slot_id	<u>year</u>			
					grade			

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;
  
```

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

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

- **delete from** *a relation* **where** condition

```
delete from instructor  
where dept name in (select dept name  
                        from department  
                        where building = 'Watson');
```

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

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 *instructor*, the average salary changes
- Solution used in SQL:
 - First, compute **avg** (salary) and find all tuples to delete
 - Next, delete all tuples found above (without recomputing **avg** or retesting the tuples)

department		instructor		teaches	section	takes	student	course	advisor
<u>dept_name</u>		<u>ID</u>		<u>ID</u>	<u>course_id</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	
building		name		<u>course_id</u>	<u>sec_id</u>	<u>course_id</u>	name	title	<u>s_id</u>
		dept_name		<u>sec_id</u>	<u>semester</u>	<u>sec_id</u>	dept_name	dept_name	<u>i_id</u>
budget		salary		<u>semester</u>	<u>year</u>	<u>semester</u>	tot_cred	credits	
				<u>year</u>	<u>building</u>	<u>year</u>			
					<u>room_number</u>	<u>grade</u>			
					<u>time_slot_id</u>				

Insertion

- Add a new tuple to *course*

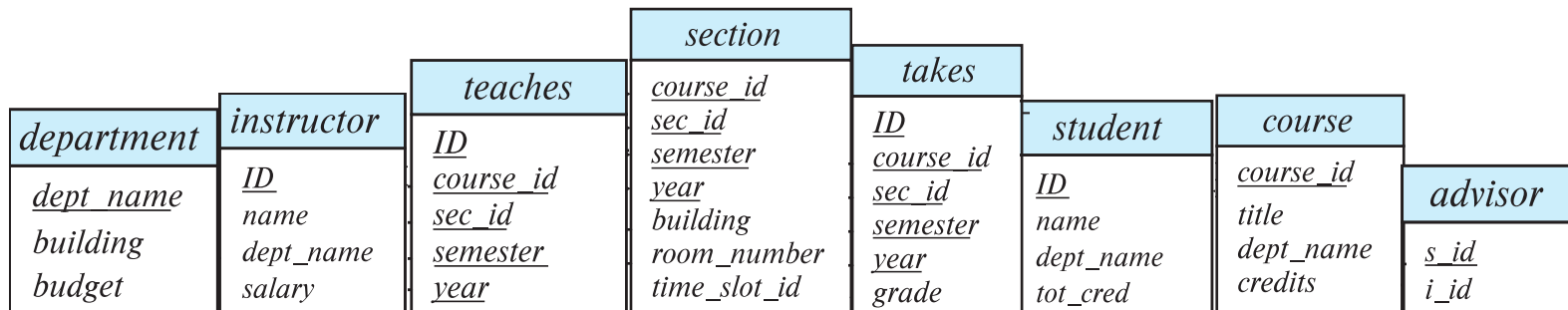
```
insert into course
values ('CS-437', 'Database Systems', 'Comp. Sci.', 4);
```

- 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.)

- Make each student in the Music department who has earned more than 144 credit hours an instructor in the Music department with a salary of \$18,000.

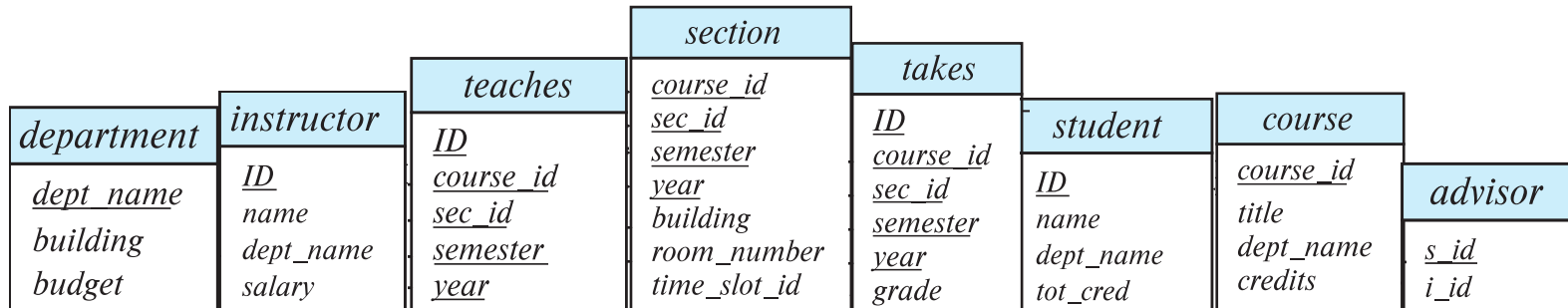
```
insert into instructor
select ID, name, dept_name, 18000
from student
where dept_name = 'Music' and total_cred > 144;
```

- 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

1. Give a 5% salary raise to all instructors
2. Give a 5% salary raise to those instructors who earn less than 70000
3. Give a 5% salary raise to instructors whose salary is less than average

department		instructor		teaches		section		takes		student		course		advisor	
<u>dept_name</u>		<u>ID</u>	name	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	<u>sec_id</u>	<u>course_id</u>	<u>sec_id</u>	<u>ID</u>	name	<u>course_id</u>	title	<u>s_id</u>	<u>i_id</u>
building		dept_name		<u>sec_id</u>	<u>semester</u>	building	room_number	<u>semester</u>	<u>year</u>	dept_name		dept_name	credits		
budget		salary		<u>year</u>		time_slot_id		grade		tot_cred					

Updates (Cont.)

- Increase salaries of instructors whose salary is over \$100,000 by 3%, and all others by a 5%
 - **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

```

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

department		instructor		teaches	section	takes	student	course	advisor
<u>dept_name</u>	<u>ID</u>	<u>ID</u>	<u>name</u>	<u>ID</u>	<u>course_id</u>	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	
building	dept_name	name	dept_name	sec_id	semester	sec_id	semester	title	s_id
budget	salary	year	year	building	room_number	year	grade	dept_name	i_id
				time_slot_id				credits	

Updates with Scalar Subqueries

- Recompute and update `tot_cred` 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_cred* 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

		<i>teaches</i>		<i>section</i>	<i>takes</i>		<i>student</i>	<i>course</i>	<i>advisor</i>
<i>department</i>	<i>instructor</i>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<u><i>sec_id</i></u>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<u><i>ID</i></u>	<u><i>course_id</i></u>	
<u><i>dept_name</i></u>	<u><i>ID</i></u>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>course_id</i>	<i>sec_id</i>	<i>name</i>	<i>title</i>	<u><i>s_id</i></u>
<i>building</i>	<i>dept_name</i>	<i>semester</i>	<i>building</i>	<i>room_number</i>	<i>semester</i>	<i>year</i>	<i>dept_name</i>	<i>dept_name</i>	<i>i_id</i>
<i>budget</i>	<i>salary</i>	<i>year</i>	<i>time_slot_id</i>		<i>grade</i>		<i>tot_cred</i>	<i>credits</i>	

Join conditions

- List the names of students instructors along with the titles of courses that they have taken
 - Natural Join with **Using** Clause
 - Join condition with **on** condition

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

Join types

- Three forms of outer join:
 - Natural left outer join $course \bowtie_{\text{prereq}}$
 - Natural right outer join $course \bowtie_{\text{prereq}}$
 - Natural full outer join $course \bowtie_{\text{prereq}}$

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

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

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

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

<i>course_id</i>	<i>prereq_id</i>
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

<i>department</i>		<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u>	<i>building</i>	<u><i>ID</i></u>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<u><i>sec_id</i></u>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<i>s_id</i>
<i>budget</i>		<i>name</i>	<i>course_id</i>	<i>semester</i>	<i>course_id</i>	<i>name</i>	<i>title</i>	<i>i_id</i>
		<i>dept_name</i>	<i>sec_id</i>	<i>year</i>	<i>sec_id</i>	<i>dept_name</i>	<i>dept_name</i>	
		<i>salary</i>	<i>semester</i>	<i>building</i>	<i>semester</i>	<i>tot_cred</i>	<i>credits</i>	
			<i>year</i>	<i>room_number</i>	<i>year</i>			
				<i>time_slot_id</i>	<i>grade</i>			

Join

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

Join conditions
natural on < predicate > using (A_1, A_2, \dots, A_n)

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

<i>course_id</i>	<i>prereq_id</i>
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<i>s_id</i> <i>i_id</i>

Joined Relations – Examples

- course natural right outer join prereq

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

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

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

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<i>s_id</i> <i>i_id</i>

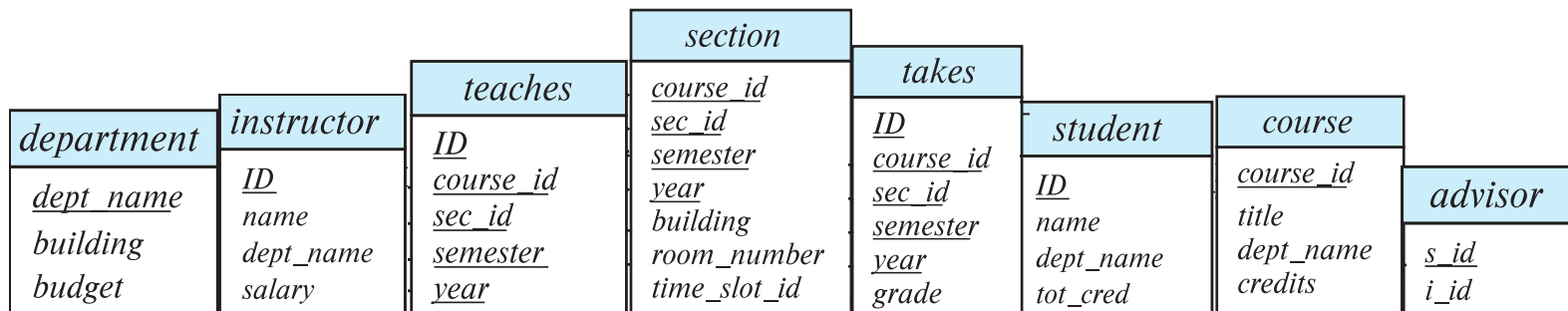
Joined Relations – Examples

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

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prereq_id</i>	<i>course_id</i>
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*

<i>course_id</i>	<i>title</i>	<i>dept_name</i>	<i>credits</i>	<i>prereq_id</i>	<i>course_id</i>
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	<i>null</i>	<i>null</i>



Joined Relations – Examples

- course natural right outer join prereq

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

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

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

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<i>s_id</i> <i>i_id</i>

View

- A **view** provides a mechanism to hide certain data from the view of certain users.
 - 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
```
 - **create view** *v* **as** < query expression >
1. A view of instructors without their salary
 2. Find all instructors in the Biology department
 3. Create a view of department salary totals

			section				
department	instructor	teaches		takes	student	course	advisor
<u>dept_name</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	<u>s_id</u>
building	name	<u>course_id</u>	<u>sec_id</u>	<u>course_id</u>	name	title	i_id
budget	dept_name	<u>sec_id</u>	<u>semester</u>	<u>sec_id</u>	dept_name	dept_name	
	salary	<u>semester</u>	building	<u>semester</u>	tot_cred	credits	
		<u>year</u>	room_number	<u>year</u>			
			time_slot_id	grade			

Define Views using other Views

- create view ***physics_fall_2017*** 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* = '2017';
- create view ***physics_fall_2017_watson*** as
 select *course_id*, *room_number*
 from ***physics_fall_2017***
 where *building* = 'Watson';

department		instructor		teaches	section	takes	student	course	advisor
<u>dept_name</u>	<u>ID</u>	<u>ID</u>	<u>name</u>	<u>ID</u>	<u>course_id</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	
<i>building</i>	<i>dept_name</i>	<i>dept_name</i>	<i>salary</i>	<u><i>sec_id</i></u>	<u><i>semester</i></u>	<u><i>course_id</i></u>	<u><i>sec_id</i></u>	<u><i>title</i></u>	<u><i>s_id</i></u>
<i>budget</i>				<u><i>semester</i></u>	<u><i>year</i></u>	<u><i>sec_id</i></u>	<u><i>semester</i></u>	<u><i>dept_name</i></u>	<u><i>i_id</i></u>
				<u><i>year</i></u>	<u><i>building</i></u>	<u><i>year</i></u>	<u><i>grade</i></u>	<u><i>credits</i></u>	
					<u><i>room_number</i></u>				
					<u><i>time_slot_id</i></u>				

View Expansion

- Expand the view :

```
create view physics_fall_2017_watson as
select course_id, room_number
from physics_fall_2017
where building= 'Watson'
```

- To: create view **physics_fall_2017_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 = '2017')
where building= 'Watson';
```

department		instructor		teaches	section	takes	student	course	advisor
<u>dept_name</u>	<u>ID</u>	<u>ID</u>	<u>name</u>	<u>ID</u>	<u>course_id</u>	<u>ID</u>	<u>ID</u>	<u>course_id</u>	
building	dept_name	name	dept_name	course_id	sec_id	course_id	name	title	s_id
budget	salary	semester		sec_id	year	sec_id	dept_name	dept_name	i_id
		year		semester	building	semester	tot_cred	credits	
				year	room_number	year			
					time_slot_id	grade			

Views

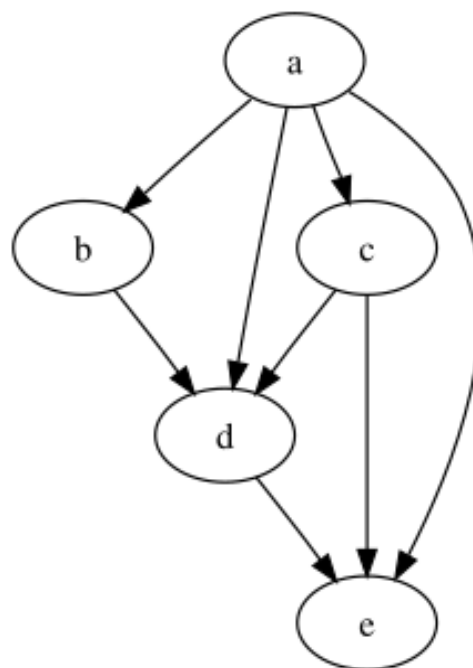
- Materialized Views
- Update Views
 - Add a new tuple to *faculty* view which we defined earlier
insert into *faculty* values ('30765', 'Green', 'Music');

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

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');
- Issues
 - 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.

Dependency Graph of Views should be a DAG



<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

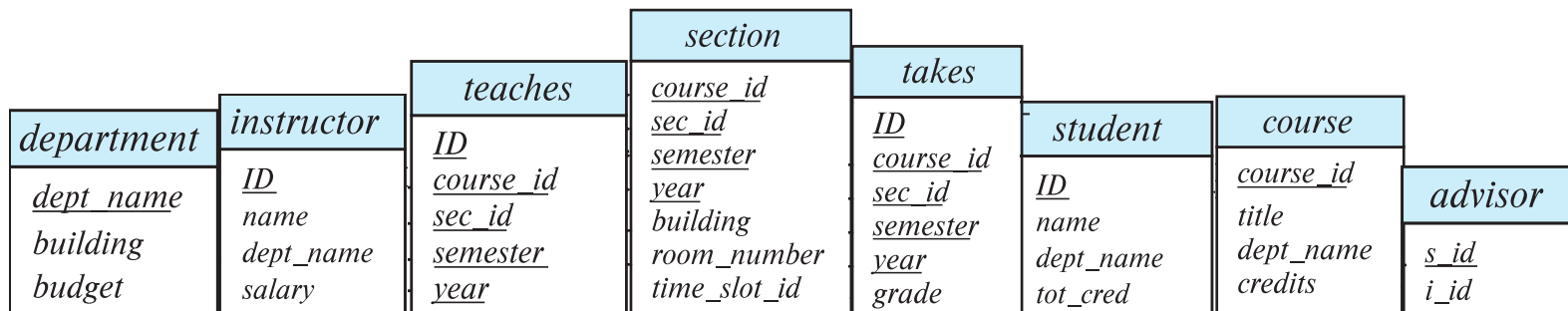
Query Quest

1. Display a list of all instructors, showing their ID, name, and the number of sections that they have taught. Make sure to show the number of sections as 0 for instructors who have not taught any section. Your query should use an outer join, and should not use scalar subqueries.
2. Outer join expressions can be computed in SQL without using the SQL outer join operation. To illustrate this fact, show how to rewrite each of the following SQL queries without using the outer join expression.
 1. **select * from student natural left outer join takes**
 2. (hard) **select * from student natural full outer join takes**

				section				
department	instructor	teaches			takes	student	course	advisor
<u>dept_name</u> building budget	<u>ID</u> name dept_name salary	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u>		<u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> building room_number time_slot_id	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> grade	<u>ID</u> name dept_name tot_cred	<u>course_id</u> title dept_name credits	<u>s_id</u> <u>i_id</u>

Integrity Constraints

- 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



Constraints on a Single Relation

- **not null**
 - *name* **varchar(20) not null**
budget **numeric(12,2) not null**
- **primary key**
- **unique** (A_1, A_2, \dots, A_m)
 - Candidate keys are permitted to be null (in contrast to primary keys).
- **check** (P), where P is a predicate (read DDL.sql)

create table department

```
(dept_name      varchar(20), building      varchar(15),
 budget        numeric(12,2) check (budget > 0),
primary key (dept_name));
```

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <i>year</i> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

- The **check** (P) clause specifies a predicate P that must be satisfied by every tuple in a relation.
- Example: ensure that semester is one of fall, winter, spring or summer

```
(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'))))
```

```
check (time_slot_id in (select time_slot_id from time_slot))
```

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

Referential Integrity

- **foreign key (*dept_name*) references *department***
 - By default, a foreign key references the primary-key attributes of the referenced table.
 - SQL allows a list of attributes of the referenced relation to be specified explicitly.

foreign key (*dept_name*) references *department* (*dept_name*)

The specified list of attributes must be declared as a superkey of the referenced relation, using either a primary key constraint or a unique constraint.

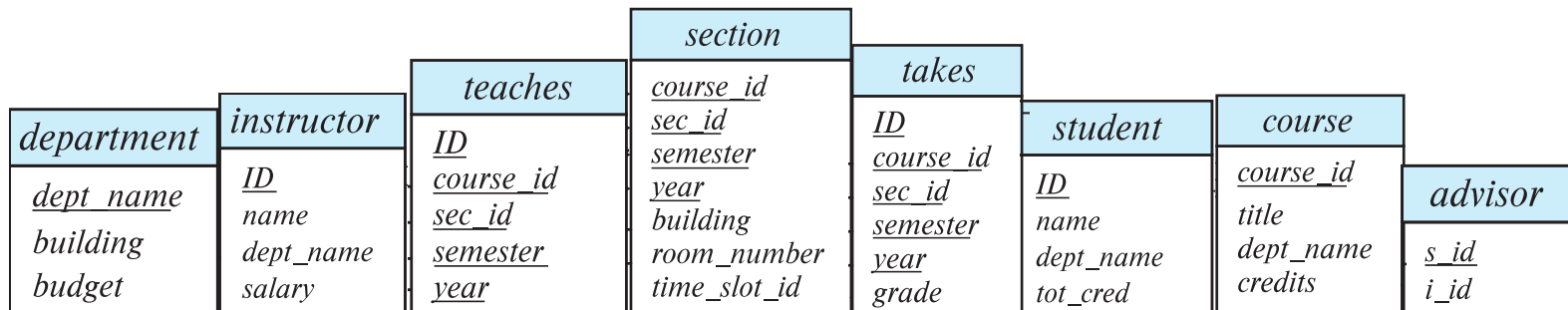
<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

Actions in Referential Integrity

- When a referential-integrity constraint is violated, the normal procedure is to reject the action that caused the violation.
- An alternative, in case of delete or update is to cascade

```
create table course (
    ...
    dept_name varchar(20),
    foreign key (dept_name) references department
    on delete cascade
    on update cascade,
    ...)
```

- Instead of cascade we can use :
 - set null,
 - set default



Integrity Constraint Violation

- **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

		<i>teaches</i>		<i>section</i>	<i>takes</i>		<i>course</i>	<i>advisor</i>
<i>department</i>	<i>instructor</i>	<i>ID</i>	<i>course_id</i>	<i>course_id</i>	<i>ID</i>	<i>student</i>	<i>course_id</i>	
<i>dept_name</i>	<i>ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>sec_id</i>	<i>course_id</i>	<i>ID</i>	<i>title</i>	<i>s_id</i>
<i>building</i>	<i>name</i>	<i>sec_id</i>	<i>semester</i>	<i>semester</i>	<i>sec_id</i>	<i>name</i>	<i>dept_name</i>	<i>i_id</i>
<i>budget</i>	<i>dept_name</i>	<i>year</i>	<i>year</i>	<i>building</i>	<i>year</i>	<i>dept_name</i>	<i>credits</i>	
	<i>salary</i>			<i>room_number</i>	<i>grade</i>	<i>tot_cred</i>		
				<i>time_slot_id</i>				

Built-in Data Types in SQL

- **date**: Example: **date** '2005-7-27'
- **time**: Example: **time** '09:00:30' **time** '09:00:30.75'
- **Timestamp** Example: **timestamp** '2005-7-27 09:00:30.75'
- **interval**: Subtracting a date/time/timestamp value from another gives an interval value
- Large objects (photos, videos, CAD files, etc.) are stored as a *large object*:
 - **blob**: binary large object
 - **clob/text**: character large object
 - When a query returns a large object, a pointer is returned rather than the large object itself.

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <i>sec_id</i> <u><i>semester</i></u> <u><i>year</i></u>	<i>course_id</i> <u><i>sec_id</i></u> <i>semester</i> <i>year</i> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <i>sec_id</i> <i>semester</i> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<i>s_id</i> <i>i_id</i>

Index Creation

- We create an index with the **create index** command
create index <name> **on** <relation-name> (attribute);
- **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*)
- The query:
select *
from *student*
where *ID* = '12345'

Demo: EXPLAIN QUERY PLAN

		<i>teaches</i>		<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<i>department</i>	<i>instructor</i>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<u><i>course_id</i></u>	<u><i>ID</i></u>	<u><i>ID</i></u>	<u><i>course_id</i></u>	
<i>dept_name</i>	<u><i>ID</i></u>	<i>sec_id</i>	<i>semester</i>	<i>sec_id</i>	<i>course_id</i>	<i>name</i>	<i>title</i>	<u><i>s_id</i></u>
<i>building</i>	<i>dept_name</i>	<i>semester</i>	<i>building</i>	<i>semester</i>	<i>sec_id</i>	<i>dept_name</i>	<i>dept_name</i>	<i>i_id</i>
<i>budget</i>	<i>salary</i>	<i>year</i>	<i>room_number</i>	<i>year</i>	<i>grade</i>	<i>tot_cred</i>	<i>credits</i>	

Transactions

- The transaction must end with one of the following statements:
 - **Commit work.**
 - **Rollback work.**
- Atomic transaction
- Isolation from concurrent transactions
- ACID
 - Consistency and Durability.
- Demo: transaction

				section				
department	instructor	teaches			takes	student	course	advisor
<u>dept_name</u> building budget	<u>ID</u> name dept_name salary	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u>	<u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> building room_number time_slot_id		<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> grade	<u>ID</u> name dept_name tot_cred	<u>course_id</u> title dept_name credits	<u>s_id</u> <u>i_id</u>

Assertions

- An **assertion** is a predicate expressing a condition that we wish the database always to satisfy.
- The following constraints, can be expressed using assertions:
 - For each tuple in the *student* relation, the value of the attribute *tot_cred* must equal the sum of credits of courses that the student has completed successfully.
 - An instructor cannot teach in two different classrooms in a semester in the same time slot
- An assertion in SQL takes the form:
create assertion <assertion-name> **check** (<predicate>);

<i>department</i>		<i>instructor</i>		<i>teaches</i>		<i>section</i>		<i>takes</i>		<i>student</i>		<i>course</i>		<i>advisor</i>	
<u>dept_name</u>		<u>ID</u>		<u>ID</u>		<u>course_id</u>		<u>ID</u>		<u>ID</u>		<u>course_id</u>		<u>s_id</u>	
building		name		course_id		sec_id		course_id		name		title		i_id	
budget		dept_name		sec_id		semester		sec_id		dept_name		dept_name			
		salary		semester		building		semester		tot_cred		credits			
				year		room_number		year							
						time_slot_id		grade							

Authorization

- We may assign a user several forms of authorizations 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.
- Each of these types of authorizations is called a **privilege**. We may authorize the user all, none, or a combination of these types of privileges on specified parts of a database, such as a relation or a view.

		<i>teaches</i>		<i>section</i>	<i>takes</i>		<i>course</i>	<i>advisor</i>
<i>department</i>	<i>instructor</i>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<u><i>course_id</i></u>	<u><i>ID</i></u>	<u><i>course_id</i></u>	<u><i>student</i></u>	
<u><i>dept_name</i></u>	<u><i>ID</i></u>	<i>name</i>	<i>sec_id</i>	<i>semester</i>	<i>course_id</i>	<i>sec_id</i>	<i>name</i>	<u><i>s_id</i></u>
<i>building</i>	<i>dept_name</i>	<i>semester</i>	<i>building</i>	<i>room_number</i>	<i>semester</i>	<i>year</i>	<i>dept_name</i>	<i>i_id</i>
<i>budget</i>	<i>salary</i>	<i>year</i>	<i>time_slot_id</i>	<i>grade</i>	<i>tot_cred</i>	<i>credits</i>		

Authorization (Cont.)

- 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.

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <i>year</i> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

Authorization Specification in SQL

- The **grant** statement is used to confer authorization
 - **grant** <privilege list> **on** <relation or view > **to** <user list>
- <user list> is:
 - a user-id
 - **public**, which allows all valid users the privilege granted
 - A role (more on this later)
- Example:
 - **grant select on department to** Amit, Satoshi
- 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).

			section				
	instructor	teaches		takes		course	
department			course_id	ID	student		
<u>dept_name</u>	<u>ID</u>	<u>ID</u>	<u>sec_id</u>	<u>course_id</u>	<u>ID</u>	<u>course_id</u>	advisor
building	name	<u>sec_id</u>	<u>semester</u>	<u>sec_id</u>	name	title	<u>s_id</u>
budget	dept_name	<u>semester</u>	building	<u>semester</u>	dept_name	dept_name	i_id
	salary	<u>year</u>	room_number	year	tot_cred	credits	
			time_slot_id	grade			

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

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u>dept_name</u> building budget	<u>ID</u> name dept_name salary	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u>	<u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> building room_number time_slot_id	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> grade	<u>ID</u> name dept_name tot_cred	<u>course_id</u> title dept_name credits	<u>s_id</u> <u>i_id</u>

Revoking Authorization in SQL

- The **revoke** statement is used to revoke authorization.
revoke <privilege list> **on** <relation or view> **from** <user list>
- Example:
revoke select on student 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.

		<i>teaches</i>		<i>section</i>	<i>takes</i>		<i>student</i>	<i>course</i>	<i>advisor</i>
<i>department</i>	<i>instructor</i>	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	<u>sec_id</u>	<u>semester</u>	<u>ID</u>	<u>course_id</u>	
<u>dept_name</u>	<u>ID</u>	<u>course_id</u>	<u>sec_id</u>	<u>semester</u>	<u>course_id</u>	<u>sec_id</u>	<u>name</u>	<u>title</u>	<u>s_id</u>
<i>building</i>	<i>dept_name</i>	<i>semester</i>	<i>year</i>	<i>building</i>	<i>sec_id</i>	<i>semester</i>	<i>dept_name</i>	<i>dept_name</i>	<i>i_id</i>
<i>budget</i>	<i>salary</i>	<i>year</i>	<i>time_slot_id</i>	<i>room_number</i>	<i>year</i>	<i>grade</i>	<i>tot_cred</i>	<i>credits</i>	

Roles

- A **role** is a way to distinguish among various users as far as what these users can access/update in the database.
- To create a role we use:
 - create a role** <name>
- Example:
 - **create role** instructor
- Once a role is created we can assign “users” to the role using:
 - **grant** <role> **to** <users>

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u>dept_name</u> building budget	<u>ID</u> name dept_name salary	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u>	<u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> building room_number time_slot_id	<u>ID</u> <u>course_id</u> <u>sec_id</u> <u>semester</u> <u>year</u> grade	<u>ID</u> name dept_name tot_cred	<u>course_id</u> title dept_name credits	<u>s_id</u> <u>i_id</u>

Roles Example

- **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;

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

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*?

		<i>teaches</i>		<i>section</i>	<i>takes</i>		<i>course</i>	<i>advisor</i>
<i>department</i>	<i>instructor</i>	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	<u>ID</u>	<u>course_id</u>	<u>course_id</u>	
<u>dept_name</u>	<u>ID</u>	<u>sec_id</u>	<u>semester</u>	<u>sec_id</u>	<u>sec_id</u>	<u>semester</u>	<u>title</u>	<u>s_id</u>
<i>building</i>	<i>name</i>	<i>year</i>	<i>building</i>	<i>year</i>	<i>year</i>	<i>grade</i>	<i>dept_name</i>	<i>i_id</i>
<i>budget</i>	<i>dept_name</i>		<i>room_number</i>	<i>time_slot_id</i>			<i>credits</i>	
	<i>salary</i>							

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**;
 - And more!

<i>department</i>	<i>instructor</i>	<i>teaches</i>	<i>section</i>	<i>takes</i>	<i>student</i>	<i>course</i>	<i>advisor</i>
<u><i>dept_name</i></u> <i>building</i> <i>budget</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>salary</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u>	<u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>building</i> <i>room_number</i> <i>time_slot_id</i>	<u><i>ID</i></u> <u><i>course_id</i></u> <u><i>sec_id</i></u> <u><i>semester</i></u> <u><i>year</i></u> <i>grade</i>	<u><i>ID</i></u> <i>name</i> <i>dept_name</i> <i>tot_cred</i>	<u><i>course_id</i></u> <i>title</i> <i>dept_name</i> <i>credits</i>	<u><i>s_id</i></u> <u><i>i_id</i></u>

FIN

Any questions?