Chapter 4:
Introduction to SQL

Outline

- Basic Query Structure of SQL Queries
- Additional Basic Operations
- Set Operations
- Null Values
- Aggregate Functions
- Nested Subqueries
- Modification of the Database

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 5.

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

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

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

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from instructor
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where salary between 90000 and 100000
```

- Tuple comparison

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

Set Operations

- ***Section(course_id,sem,year)***

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(**select** *course_id* **from** *section* **where** *sem* = 'Fall' **and** *year* = 2017)
union
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```
(select course_id  from section where sem = 'Fall' and year = 2017)
    except
    (select course_id  from section where sem = 'Spring' and year = 2018)
```

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- To retain all duplicates use the
  - **union all**,
  - **intersect all**
  - **except all**.

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    select *name*
    from *instructor*
    where *salary* **is null**
- The predicate **is not null** succeeds if the value on which it is applied is not null.

Null Values (Cont.)

- SQL treats as **unknown** the result of any comparison involving a null value (other than predicates **is null** and **is not null**).
  - Example*: 5* < **null** or **null** <> **null** or **null** = **null**

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    (*unknown* **or** *unknown)* = *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 Examples

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

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

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- Find the total number of instructors who teach a course in the Spring 2018 semester

  select count (**distinct** *ID*)
  from *teaches*
  where *semester* = 'Spring' **and** *year* = 2018;

Aggregate Functions Examples

- 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 2018 semester

```
select count (distinct ID)
from teaches
where semester = 'Spring' and year = 2018;
```

- 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

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```
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from instructor
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- The GROUP BY statement groups rows that have the **same values** into summary rows.

Aggregate Functions – Group By

- Find the average salary of instructors in each department

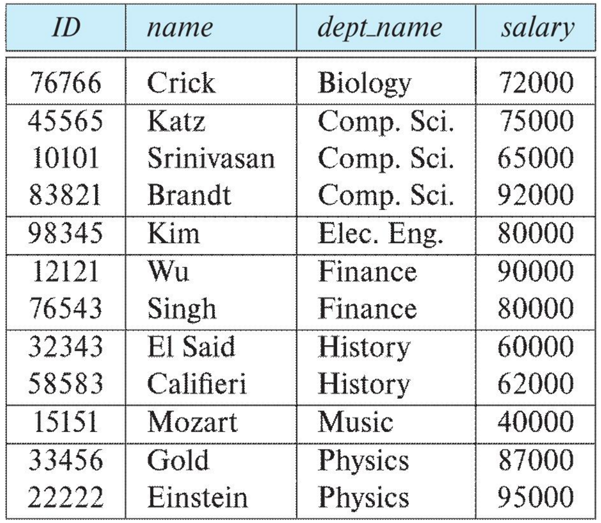
  select *dept_name*, **avg** (*salary*) **as** *avg_salary*
  from *instructor*
  group by *dept_name*;

- The GROUP BY statement groups rows that have the **same values** into summary rows.
- The GROUP BY statement is often used with aggregate functions (COUNT, MAX, MIN, SUM, AVG) to group the result-set by one or more columns.

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

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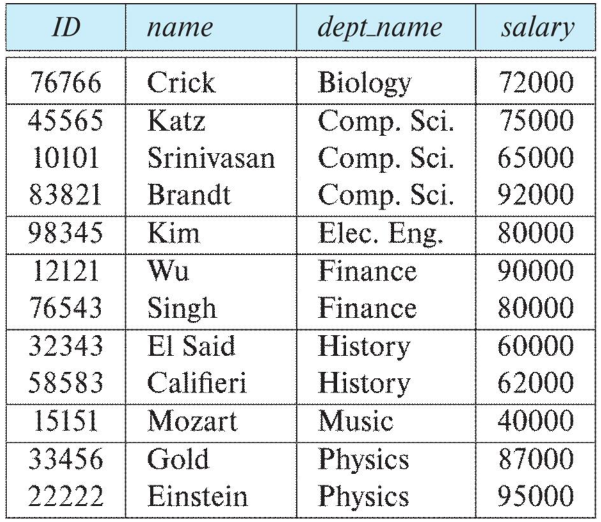

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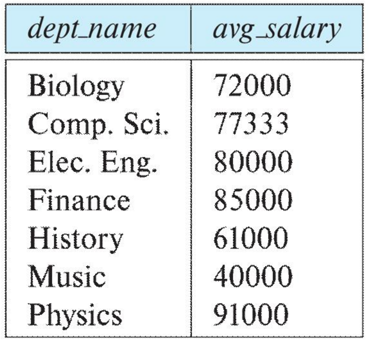

dept_name	*avg_salary*
Biology	72000
Comp. Sci.	77333
Elec. Eng.	80000
Finance	85000
History	61000
Music	40000
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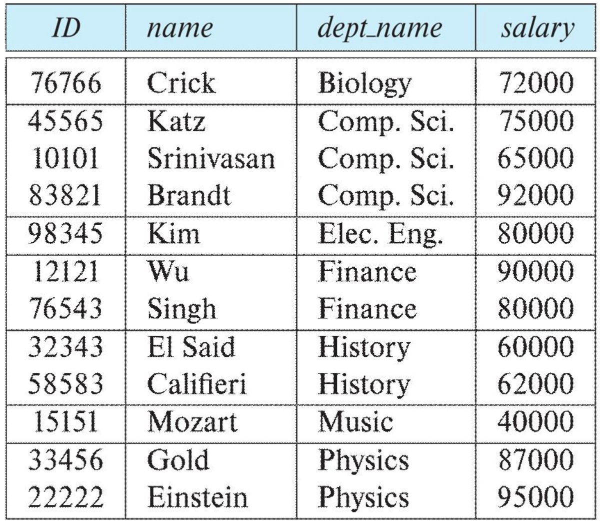
Aggregation (Cont.)

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



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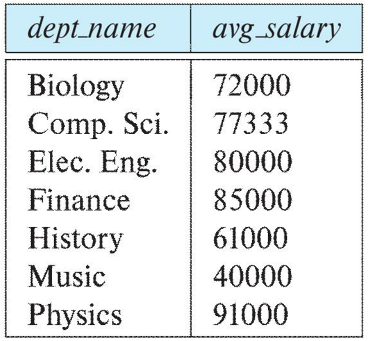

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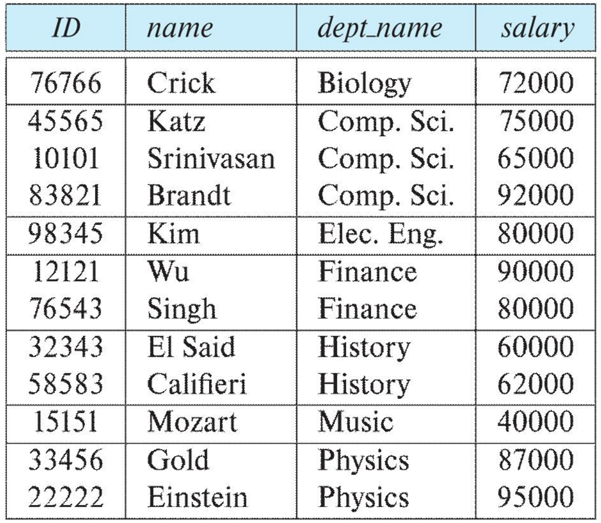
Aggregation (Cont.)

- 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*;



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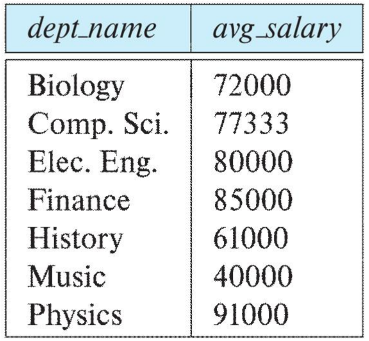

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Aggregate Functions – Having Clause

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

- The HAVING clause was added to SQL because the WHERE keyword could not be used with **aggregate functions**.

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) as
avg_salary
from instructor
group by dept_name
having avg (salary) > 42000;
```

- The HAVING clause was added to SQL because the WHERE keyword could not be used with **aggregate functions**.

Having Clause

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

```
SELECT column_name(s)
FROM table_name
WHERE condition
GROUP BY column_name(s)
HAVING condition
ORDER BY column_name(s);
```

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

    B <operation> (subquery)

    B is an attribute and <operation> to be defined later.
  - **Select clause:**

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

Nested Subqueries

```
SELECT DISTINCT c.city
FROM   Company c,
       Product pr,
       Purchase p
WHERE  c.name = pr.maker
  AND  pr.name = p.product
  AND  p.buyer = ‘Joe Blow’
```

Set Membership

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- Find courses offered in Fall 2017 and in Spring 2018

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```
select distinct course_id
from section
where semester = 'Fall' and year= 2017 and
          course_id in (select course_id
                                    from section
                                    where semester = 'Spring' and year= 2018);
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Set Membership

- Find courses offered in Fall 2017 and in Spring 2018

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where semester = 'Fall' and year= 2017 and
          course_id  not in (select course_id
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- Find courses offered in Fall 2017 but not in Spring 2018

Set Membership (Cont.)

- Name all instructors whose name is neither “Mozart” nor Einstein”

Set Membership (Cont.)

- Name all instructors whose name is neither “Mozart” nor Einstein”

  select distinct *name*
  from *instructor*
  where *name* **not in** ('Mozart', 'Einstein')

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

Set Membership (Cont.)

- Name all instructors whose name is neither “Mozart” nor Einstein”

```
select distinct name
from instructor
where  name not in ('Mozart', 'Einstein')
```

- 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

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';
```

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

- Same query using > **some** clause

Definition of “some” Clause

- F <comp> **some** $r \Leftrightarrow \exists\ t \in r$ such that (F <comp> t)
  Where <comp> can be: $<,\ \leq,\ >,\ =,\ \neq$

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

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

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

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

(= **some**) $\equiv$ **in**

However, ($\neq$ **some**) $\not\equiv$ **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

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

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

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

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

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

($\neq$ **all**) $\equiv$ **not in**

However, (= **all**) $\not\equiv$ **in**

Test for Empty Relations

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

Use of “exists” Clause

- Yet another way of specifying the query “Find all courses taught in both the Fall 2017 semester and in the Spring 2018 semester”

```
select course_id
from section as S
where semester = 'Fall' and year = 2017 and
          exists  (select *
                       from section as T
                       where semester = 'Spring' and year= 2018
                                 and S.course_id = T.course_id);
```

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

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*

Deletion

- Delete all instructors

  delete from *instructor*

- Delete all instructors from the Finance department

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

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  delete from *instructor*

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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.*

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 *instructor*, 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.)

- 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

- Give a 5% salary raise to all instructors

```
update instructor
   set salary = salary * 1.05
```

- Give a 5% salary raise to those instructors who earn less than 70000

```
update instructor
    set salary = salary * 1.05
   where salary < 70000;
```

- Give a 5% salary raise to instructors whose salary is less than average

```
 update instructor
set salary = salary * 1.05
where salary <  (select avg (salary)
                 from instructor);
```

Updates (Cont.)

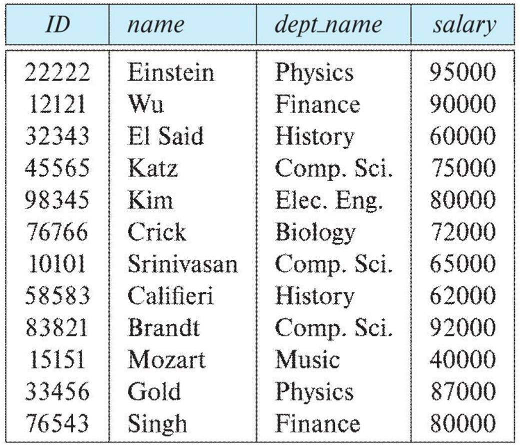
- Increase salaries of instructors whose salary is over $100,000 by 3%, and all others by a 5%
  - Write two **update** statements:

```
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)

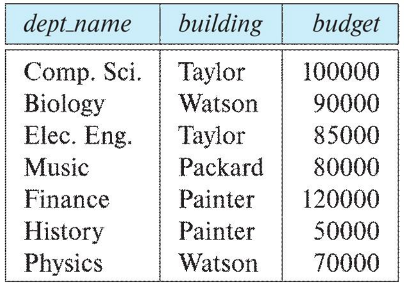
End of Chapter 4

A Sample Relational Database



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

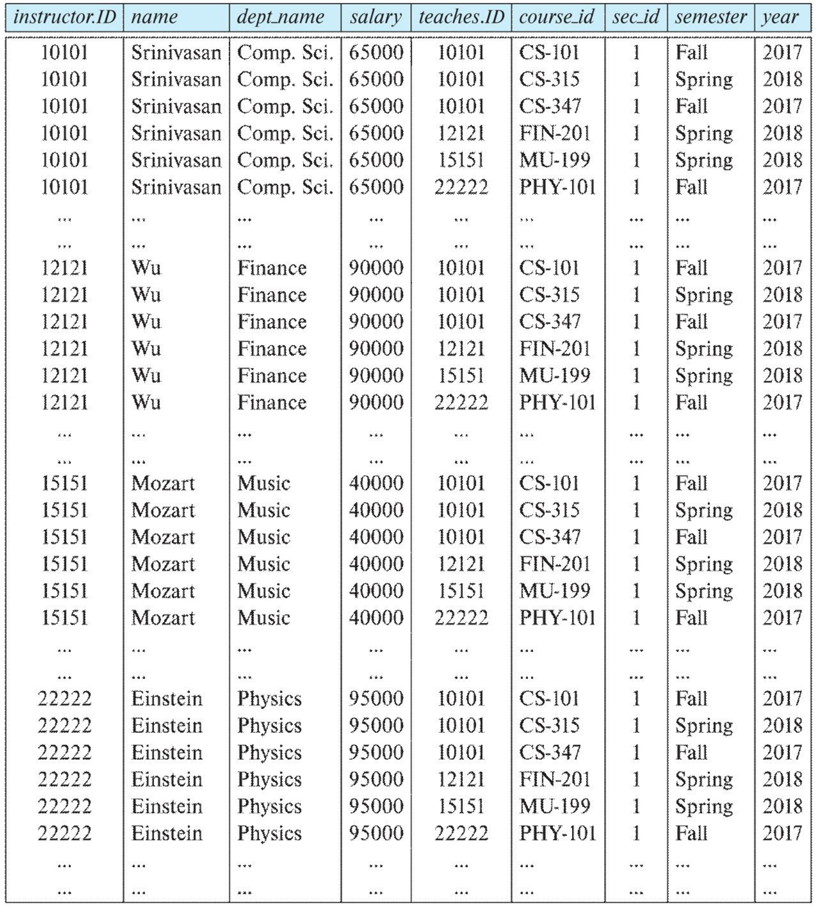
(a) The *instructor* table



dept_name	*building*	*budget*
Comp. Sci.	Taylor	100000
Biology	Watson	90000
Elec. Eng.	Taylor	85000
Music	Packard	80000
Finance	Painter	120000
History	Painter	50000
Physics	Watson	70000

(b) The *department* table

The *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
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
...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...