



**CS425 – Fall 2013**  
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**Chapter 5: Intermediate SQL**

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# Chapter 5: Intermediate SQL

- Views
- Transactions
- Integrity Constraints
- SQL Data Types and Schemas
- Access Control



**Textbook: Chapter 4**



# Views

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

```
select ID, name, dept_name  
from instructor
```

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



# View Definition

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

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

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

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



# Example Views

- A view of instructors without their salary

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

- Find all instructors in the Biology department

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

- Create a view of department salary totals

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



# Views Defined Using Other Views

- **create view *physics\_fall\_2009* as**  
**select** *course.course\_id, sec\_id, building, room\_number*  
**from** *course, section*  
**where** *course.course\_id = section.course\_id*  
**and** *course.dept\_name = 'Physics'*  
**and** *section.semester = 'Fall'*  
**and** *section.year = '2009'* ;
- **create view *physics\_fall\_2009\_watson* as**  
**select** *course\_id, room\_number*  
**from** *physics\_fall\_2009*  
**where** *building = 'Watson'* ;



# View Expansion

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

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



# Views Defined Using Other Views

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





# View Expansion

- A way to define the meaning of views defined in terms of other views.
- Let view  $v_1$  be defined by an expression  $e_1$  that may itself contain uses of view relations.
- View expansion of an expression repeats the following replacement step:
  - repeat**
    - Find any view relation  $v_i$  in  $e_1$
    - Replace the view relation  $v_i$  by the expression defining  $v_i$
  - until** no more view relations are present in  $e_1$
- As long as the view definitions are not recursive, this loop will terminate



# Update of a View

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

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

This insertion must be represented by the insertion of the tuple

( ' 30765' , ' Green' , ' Music' , null)

into the *instructor* relation



# Some Updates cannot be Translated Uniquely

- **create view** *instructor\_info* as  
    **select** *ID, name, building*  
    **from** *instructor, department*  
    **where** *instructor.dept\_name= department.dept\_name;*
- **insert into** *instructor\_info* **values** (' 69987' , ' White' , ' Taylor' );
  - ▶ which department, if multiple departments in Taylor?
  - ▶ what if no department is in Taylor?
- Most SQL implementations allow updates only on simple views
  - The **from** clause has only one database relation.
  - The **select** clause contains only attribute names of the relation, and does not have any expressions, aggregates, or **distinct** specification.
  - Any attribute not listed in the **select** clause can be set to null
  - The query does not have a **group** by or **having** clause.



# And Some Not at All

- **create view** *history\_instructors* **as**  
**select** \*  
**from** *instructor*  
**where** *dept\_name*= 'History' ;
- What happens if we insert (' 25566' , ' Brown' , ' Biology' , 100000) into *history\_instructors*?



# Materialized Views

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



# Transactions

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# Transactions

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



# Transactions Example

## ■ Example Atomicity (all-or-nothing)

- Recall example from the introduction
- Relation **accounts(accID, cust, type, balance)**
- A user want to transfer \$100 from his savings (accID = 100) to his checking account (accID= 101)

**UPDATE** accounts **SET** balance = balance – 100 **WHERE** accID = 100;

**UPDATE** accounts **SET** balance = balance + 100 **WHERE** accID = 101;

- This can cause inconsistencies if the system crashes after the first update (user would loose money)
- Using a transaction either both or none of the statements are executed

**BEGIN**

**UPDATE** accounts **SET** balance = balance – 100 **WHERE** accID = 100;

**UPDATE** accounts **SET** balance = balance + 100 **WHERE** accID = 101;

**COMMIT**





# Transactions and Concurrency

- Transactions are also used to isolate concurrent actions of different users
- Recall from the introduction that if several users are modifying the database at the same time that can lead to inconsistencies
- More on that later once we talk about concurrency control



# Integrity Constraints

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# Integrity Constraints

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



# Integrity Constraints on a Single Relation

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



# Not Null and Unique Constraints

## ■ not null

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

*name* **varchar(20) not null**

*budget* **numeric(12,2) not null**

## ■ **unique** ( $A_1, A_2, \dots, A_m$ )

- The unique specification states that the attributes  $A_1, A_2, \dots, A_m$  form a candidate key.
- Candidate keys are permitted to be null (in contrast to primary keys).



# The check clause

## ■ **check** (P)

where P is a predicate

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

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



# Referential Integrity

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



# Cascading Actions in Referential Integrity

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





# Integrity Constraint Violation During Transactions

■ E.g.

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

■ How to insert a tuple without causing constraint violation ?

- insert father and mother of a person before inserting person
- OR, set father and mother to null initially, update after inserting all persons (not possible if father and mother attributes declared to be **not null**)
- OR defer constraint checking (next slide)



# Complex Check Clauses

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



# Indexes and User-Defined Types (UDTs)

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# Built-in Data Types in SQL

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



# Index Creation

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

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

*More on indices later*



# User-Defined Types

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

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

- **create table *department***  
*(dept\_name varchar (20),*  
*building varchar (15),*  
*budget Dollars);*



# Domains

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

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

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



# Large-Object Types

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





# Access Control

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# Access Control

Forms of authorization on parts of the database:

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

Forms of authorization to modify the database schema

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



# Authorization Specification in SQL

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



# Privileges in SQL

- **select**: allows read access to relation, or the ability to query using the view
  - Example: grant users  $U_1$ ,  $U_2$ , and  $U_3$  **select** authorization on the *instructor* relation:  
**grant select on *instructor* to  $U_1, U_2, U_3$**
- **insert**: the ability to insert tuples
- **update**: the ability to update using the SQL update statement
- **delete**: the ability to delete tuples.
- **all privileges**: used as a short form for all the allowable privileges



# Revoking Authorization in SQL

- The **revoke** statement is used to revoke authorization.  
**revoke** <privilege list>  
**on** <relation name or view name> **from** <user list>
- Example:  
**revoke select on** *branch* **from**  $U_1, U_2, U_3$
- <privilege-list> may be **all** to revoke all privileges the revokee may hold.
- If <revokee-list> includes **public**, all users lose the privilege except those granted it explicitly.
- If the same privilege was granted twice to the same user by different grantees, the user may retain the privilege after the revocation.
- All privileges that depend on the privilege being revoked are also revoked.



# Roles

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



# Authorization on Views

- **create view** *geo\_instructor* **as**  
(**select** \*  
**from** *instructor*  
**where** *dept\_name* = ' Geology' );
- **grant select on** *geo\_instructor* **to** *geo\_staff*
- Suppose that a *geo\_staff* member issues
  - **select** \*  
**from** *geo\_instructor*;
- What if
  - *geo\_staff* does not have permissions on *instructor*?
  - creator of view did not have some permissions on *instructor*?



# Other Authorization Features

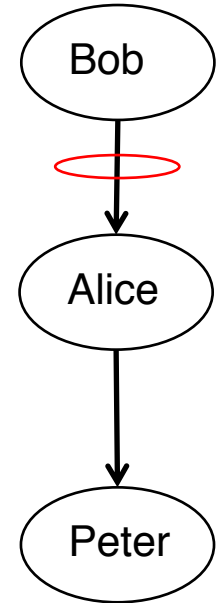
- **references** privilege to create foreign key
  - **grant reference** (*dept\_name*) **on** *department* **to** Mariano;
  - why is this required?
- transfer of privileges
  - **grant select on** *department* **to** Amit **with grant option**;
  - **revoke select on** *department* **from** Amit, Satoshi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





# Understanding RESTRICT/CASCADE

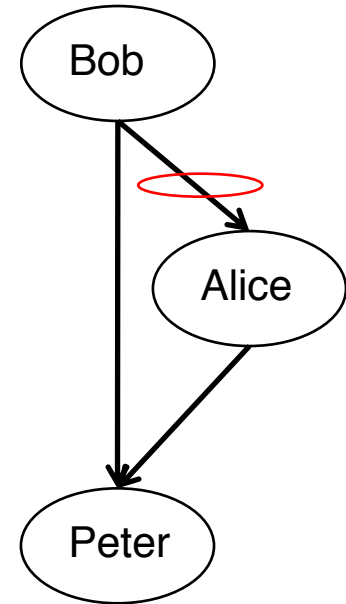
- Bob grants right X on Y to Alice with grant option
- Alice grants right X on Y to Peter
  
- **Abandoned right**
  - A right for which there is no justification anymore
  
- **revoke X on Y from Alice restrict**
  - With restrict fails if it would result in abandoned rights
  
- **revoke X on Y from Alice cascade**
  - Also revokes rights that would otherwise be abandoned





# Understanding RESTRICT/CASCADE

- Bob grants right X on Y to Alice with grant option
- Alice grants right X on Y to Peter
- Bob grants right X on Y to Peter
  
- **Abandoned privilege**
  - A privilege for which there is no justification anymore
  - Indirect justifications count
- **revoke X on Y from Alice restrict**
  - Fails: even though there exists additional justification for the privilege.
- **revoke X on Y from Alice cascade**
  - Revokes that right from Peter.
  - Peter still has the right to do X on Y





# Recap

- Views
  - Virtual
  - Materialized
  - Updates
- Integrity Constraints
  - Not null, unique, check
  - Foreign keys: referential integrity
- Access control
  - Users, roles
  - Privileges
  - **GRANT / REVOKE**
- Data types
  - Build-in types, Domains, Large Objects
  - UDTs
  - Indices



# End of Chapter 5

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# Outline

- Introduction
- Relational Data Model
- Formal Relational Languages (relational algebra)
- **SQL - Advanced**
- Database Design
- Transaction Processing, Recovery, and Concurrency Control
- Storage and File Structures
- Indexing and Hashing
- Query Processing and Optimization



# Figure 4.01

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>tot_cred</i>
00128	Zhang	Comp. Sci.	102
12345	Shankar	Comp. Sci.	32
19991	Brandt	History	80
23121	Chavez	Finance	110
44553	Peltier	Physics	56
45678	Levy	Physics	46
54321	Williams	Comp. Sci.	54
55739	Sanchez	Music	38
70557	Snow	Physics	0
76543	Brown	Comp. Sci.	58
76653	Aoi	Elec. Eng.	60
98765	Bourikas	Elec. Eng.	98
98988	Tanaka	Biology	120



## Figure 4.02

<i>ID</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>	<i>grade</i>
00128	CS-101	1	Fall	2009	A
00128	CS-347	1	Fall	2009	A-
12345	CS-101	1	Fall	2009	C
12345	CS-190	2	Spring	2009	A
12345	CS-315	1	Spring	2010	A
12345	CS-347	1	Fall	2009	A
19991	HIS-351	1	Spring	2010	B
23121	FIN-201	1	Spring	2010	C+
44553	PHY-101	1	Fall	2009	B-
45678	CS-101	1	Fall	2009	F
45678	CS-101	1	Spring	2010	B+
45678	CS-319	1	Spring	2010	B
54321	CS-101	1	Fall	2009	A-
54321	CS-190	2	Spring	2009	B+
55739	MU-199	1	Spring	2010	A-
76543	CS-101	1	Fall	2009	A
76543	CS-319	2	Spring	2010	A
76653	EE-181	1	Spring	2009	C
98765	CS-101	1	Fall	2009	C-
98765	CS-315	1	Spring	2010	B
98988	BIO-101	1	Summer	2009	A
98988	BIO-301	1	Summer	2010	<i>null</i>



# Figure 4.03

<i>ID</i>	<i>name</i>	<i>dept_name</i>	<i>tot_cred</i>	<i>course_id</i>	<i>sec_id</i>	<i>semester</i>	<i>year</i>	<i>grade</i>
00128	Zhang	Comp. Sci.	102	CS-101	1	Fall	2009	A
00128	Zhang	Comp. Sci.	102	CS-347	1	Fall	2009	A-
12345	Shankar	Comp. Sci.	32	CS-101	1	Fall	2009	C
12345	Shankar	Comp. Sci.	32	CS-190	2	Spring	2009	A
12345	Shankar	History	32	CS-315	1	Spring	2010	A
12345	Shankar	Finance	32	CS-347	1	Fall	2009	A
19991	Brandt	Music	80	HIS-351	1	Spring	2010	B
23121	Chavez	Physics	110	FIN-201	1	Spring	2010	C+
44553	Peltier	Physics	56	PHY-101	1	Fall	2009	B-
45678	Levy	Physics	46	CS-101	1	Fall	2009	F
45678	Levy	Physics	46	CS-101	1	Spring	2010	B+
45678	Levy	Physics	46	CS-319	1	Spring	2010	B
54321	Williams	Comp. Sci.	54	CS-101	1	Fall	2009	A-
54321	Williams	Comp. Sci.	54	CS-190	2	Spring	2009	B+
55739	Sanchez	Music	38	MU-199	1	Spring	2010	A-
76543	Brown	Comp. Sci.	58	CS-101	1	Fall	2009	A
76543	Brown	Comp. Sci.	58	CS-319	2	Spring	2010	A
76653	Aoi	Elec. Eng.	60	EE-181	1	Spring	2009	C
98765	Bourikas	Elec. Eng.	98	CS-101	1	Fall	2009	C-
98765	Bourikas	Elec. Eng.	98	CS-315	1	Spring	2010	B
98988	Tanaka	Biology	120	BIO-101	1	Summer	2009	A
98988	Tanaka	Biology	120	BIO-301	1	Summer	2010	<i>null</i>





# Figure 4.04

ID	name	dept_name	tot_cred	course_id	sec_id	semester	year	grade
00128	Zhang	Comp. Sci.	102	CS-101	1	Fall	2009	A
00128	Zhang	Comp. Sci.	102	CS-347	1	Fall	2009	A-
12345	Shankar	Comp. Sci.	32	CS-101	1	Fall	2009	C
12345	Shankar	Comp. Sci.	32	CS-190	2	Spring	2009	A
12345	Shankar	History	32	CS-315	1	Spring	2010	A
12345	Shankar	Finance	32	CS-347	1	Fall	2009	A
19991	Brandt	Music	80	HIS-351	1	Spring	2010	B
23121	Chavez	Physics	110	FIN-201	1	Spring	2010	C+
44553	Peltier	Physics	56	PHY-101	1	Fall	2009	B-
45678	Levy	Physics	46	CS-101	1	Fall	2009	F
45678	Levy	Physics	46	CS-101	1	Spring	2010	B+
45678	Levy	Physics	46	CS-319	1	Spring	2010	B
54321	Williams	Comp. Sci.	54	CS-101	1	Fall	2009	A-
54321	Williams	Comp. Sci.	54	CS-190	2	Spring	2009	B+
55739	Sanchez	Music	38	MU-199	1	Spring	2010	A-
70557	Snow	Physics	0	<i>null</i>	<i>null</i>	<i>null</i>	<i>null</i>	<i>null</i>
76543	Brown	Comp. Sci.	58	CS-101	1	Fall	2009	A
76543	Brown	Comp. Sci.	58	CS-319	2	Spring	2010	A
76653	Aoi	Elec. Eng.	60	EE-181	1	Spring	2009	C
98765	Bourikas	Elec. Eng.	98	CS-101	1	Fall	2009	C-
98765	Bourikas	Elec. Eng.	98	CS-315	1	Spring	2010	B
98988	Tanaka	Biology	120	BIO-101	1	Summer	2009	A
98988	Tanaka	Biology	120	BIO-301	1	Summer	2010	<i>null</i>



## Figure 4.05

ID	course_id	sec_id	semester	year	grade	name	dept_name	tot_cred
00128	CS-101	1	Fall	2009	A	Zhang	Comp. Sci.	102
00128	CS-347	1	Fall	2009	A-	Zhang	Comp. Sci.	102
12345	CS-101	1	Fall	2009	C	Shankar	Comp. Sci.	32
12345	CS-190	2	Spring	2009	A	Shankar	Comp. Sci.	32
12345	CS-315	1	Spring	2010	A	Shankar	History	32
12345	CS-347	1	Fall	2009	A	Shankar	Finance	32
19991	HIS-351	1	Spring	2010	B	Brandt	Music	80
23121	FIN-201	1	Spring	2010	C+	Chavez	Physics	110
44553	PHY-101	1	Fall	2009	B-	Peltier	Physics	56
45678	CS-101	1	Fall	2009	F	Levy	Physics	46
45678	CS-101	1	Spring	2010	B+	Levy	Physics	46
45678	CS-319	1	Spring	2010	B	Levy	Physics	46
54321	CS-101	1	Fall	2009	A-	Williams	Comp. Sci.	54
54321	CS-190	2	Spring	2009	B+	Williams	Comp. Sci.	54
55739	MU-199	1	Spring	2010	A-	Sanchez	Music	38
70557	<i>null</i>	<i>null</i>	<i>null</i>	<i>null</i>	<i>null</i>	Snow	Physics	0
76543	CS-101	1	Fall	2009	A	Brown	Comp. Sci.	58
76543	CS-319	2	Spring	2010	A	Brown	Comp. Sci.	58
76653	EE-181	1	Spring	2009	C	Aoi	Elec. Eng.	60
98765	CS-101	1	Fall	2009	C-	Bourikas	Elec. Eng.	98
98765	CS-315	1	Spring	2010	B	Bourikas	Elec. Eng.	98
98988	BIO-101	1	Summer	2009	A	Tanaka	Biology	120
98988	BIO-301	1	Summer	2010	<i>null</i>	Tanaka	Biology	120



# Figure 4.07

<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
69987	White	<i>null</i>	<i>null</i>

*instructor*

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

*department*



## Figure 4.06

### *Join types*

**inner join**  
**left outer join**  
**right outer join**  
**full outer join**

### *Join conditions*

**natural**  
**on** <predicate>  
**using** ( $A_1, A_2, \dots, A_n$ )



## Figure 4.03

