



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 instructors name and department, but not the salary. This person should see a relation described, in SQL, by

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

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



View Definition

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

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

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

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



Example Views

- A view of instructors without their salary
create view *faculty* as
 select *ID, name, dept_name*
 from *instructor*
- Find all instructors in the Biology department
select *name*
from *faculty*
where *dept_name* = 'Biology'
- Create a view of department salary totals
create view *departments_total_salary*(*dept_name, total_salary*) as
 select *dept_name, sum (salary)*
 from *instructor*
 group by *dept_name*;



Views Defined Using Other Views

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



View Expansion

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

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



Views Defined Using Other Views

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



View Expansion

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



Update of a View

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

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

This insertion must be represented by the insertion of the tuple

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

into the *instructor* relation



Some Updates cannot be Translated Uniquely

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



And Some Not at All

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



Materialized Views

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



Transactions

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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.



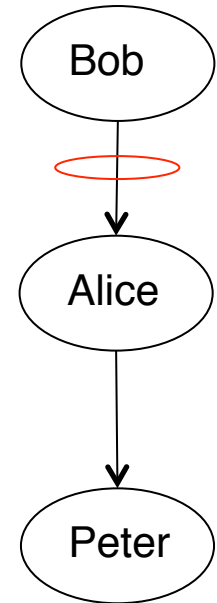
Understanding RESTRICT/CASCADE

- 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 Peter restrict**
 - With restrict fails if it would result in abandoned rights

- **revoke X on Y from Peter cascade**
 - Also revokes rights that would otherwise be abandoned

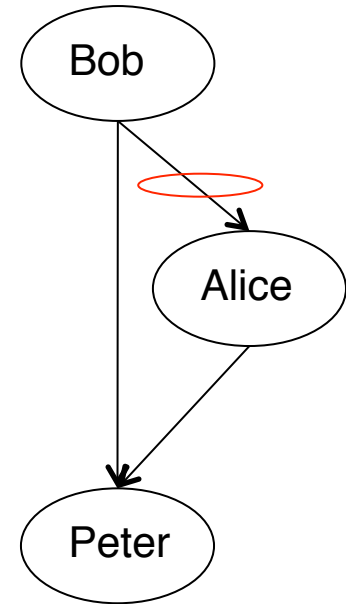




Understanding RESTRICT/CASCADE

- 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 Peter restrict**
 - Fails: even though there exists additional justification for the privilege.
- **revoke X on Y from Peter 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

| 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- |
| 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

