Database Systems
Lecture05 – Intermediate SQL (Ch.4)

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Outline

- Join Expressions
- Views
- Transactions
- Integrity Constraints
- SQL Data Types and Schemas
- Index Definition in SQL
- Authorization

Joined Relations

- **Join operations**
  - take two relations
  - combine rows from two tables, using related columns
  - return another relation

- Three types of joins:
  - Natural join
  - Inner join
  - Outer join

Natural Join in SQL

- Natural join
  - matches tuples using all common attributes
  - retains only one copy of each common column.

- E.g. List the names of instructors along with the course ID of the courses that they teaches

Instructors

ID	name	dept_name
10	Nam	Comp. Sci.
20	Alice	Electrical Eng.

Teaches

ID	c_id	semester	year
10	swe3003	Spring	2025
20	swe3003	Fall	2024
10	swe3021	Spring	2024

select *name*, *course_id*
from *instructors* **natural join** *teaches*;

Natural Join in SQL

Instructors

ID	name	dept_name
10	Alice	Comp. Sci.
20	Bob	Electrical Eng.

Teaches

ID	c_id	semester	year
10	swe3003	Spring	2025
20	swe3003	Fall	2024
10	swe3021	Spring	2024

ID	name	dept_name	c_id	semester	year
10	Alice	Comp. Sci.	swe3003	Spring	2025
10	Alice	Comp. Sci.	swe3021	Spring	2024
20	Bob	Electrical Eng.	swe3003	Fall	2024

select *name*, *course_id*
from *instructors* **natural join** *teaches*;

Natural Join in SQL

Instructors

ID	name	dept_name
10	Alice	Comp. Sci.
20	Bob	Electrical Eng.

Teaches

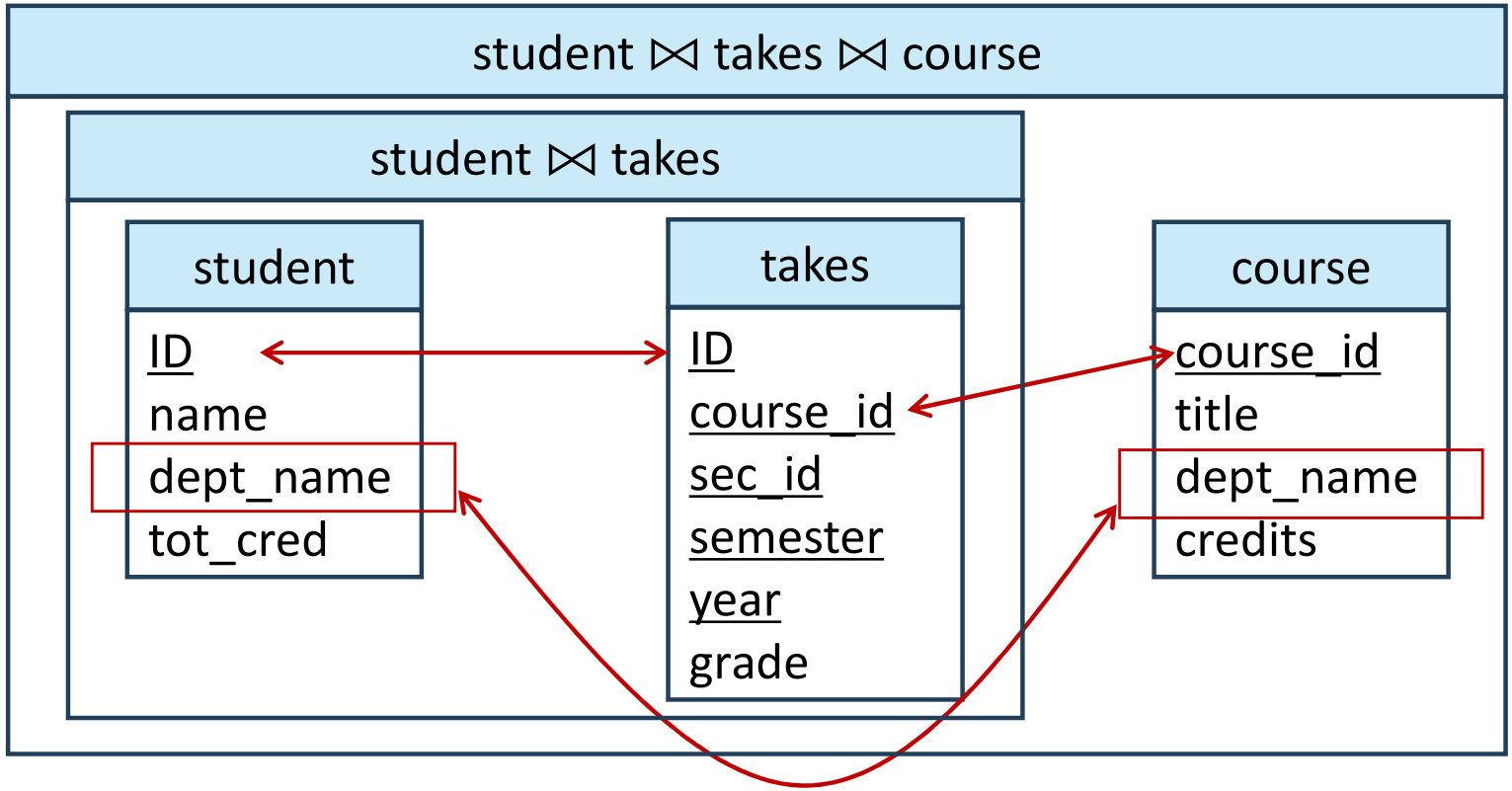
ID	c_id	semester	year
10	swe3003	Spring	2025
20	swe3003	Fall	2024
10	swe3021	Spring	2024

ID	name	dept_name	ID	c_id	semester	year
10	Alice	Comp. Sci.	10	swe3003	Spring	2025
10	Alice	Comp. Sci.	20	swe3003	Fall	2024
10	Alice	Comp. Sci.	10	swe3021	Spring	2024
20	Bob	Electrical Eng.	10	swe3003	Spring	2025
20	Bob	Electrical Eng.	20	swe3003	Fall	2024
20	Bob	Electrical Eng.	10	swe3021	Spring	2024

select *name, course_id*
from *instructors, teaches*
where *instructors.ID = teaches.ID;*

Recall: Join with *unrelated attributes with same name*

- if two columns **accidentally** happen to have the **same name**, **NATURAL JOIN** will use the column as the join condition,



- Example:

  select *name*, *title*

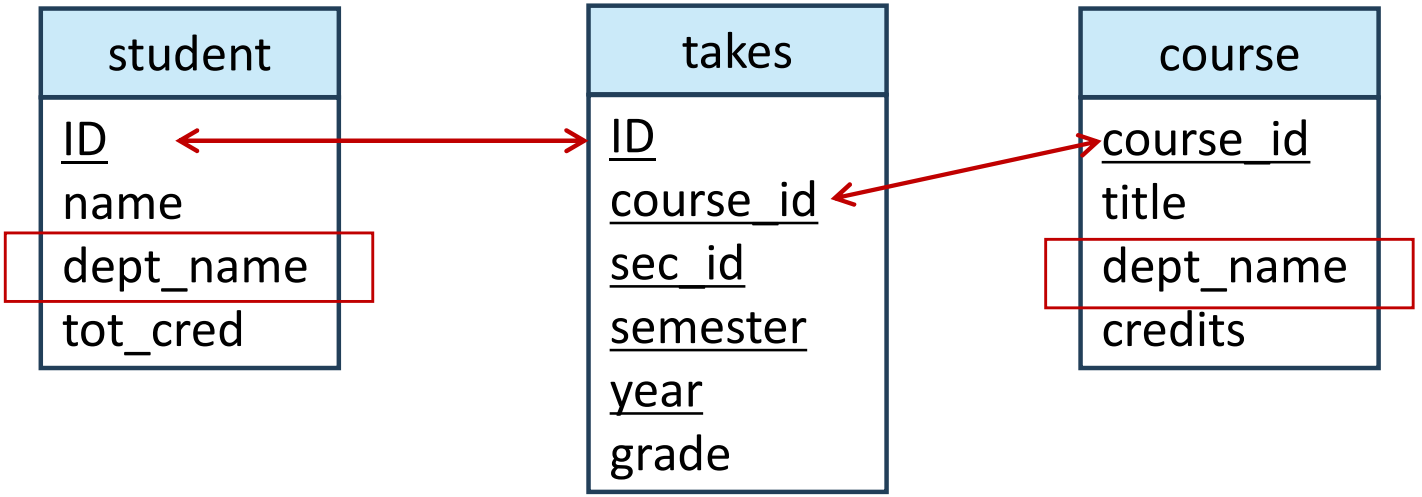
  from *student* **natural join** *takes* **natural join** *course*;

Natural Join with Using

- Join condition can be explicitly specified by the "**using**" construct.
  - To avoid the problem of ***unrelated attributes with same name***

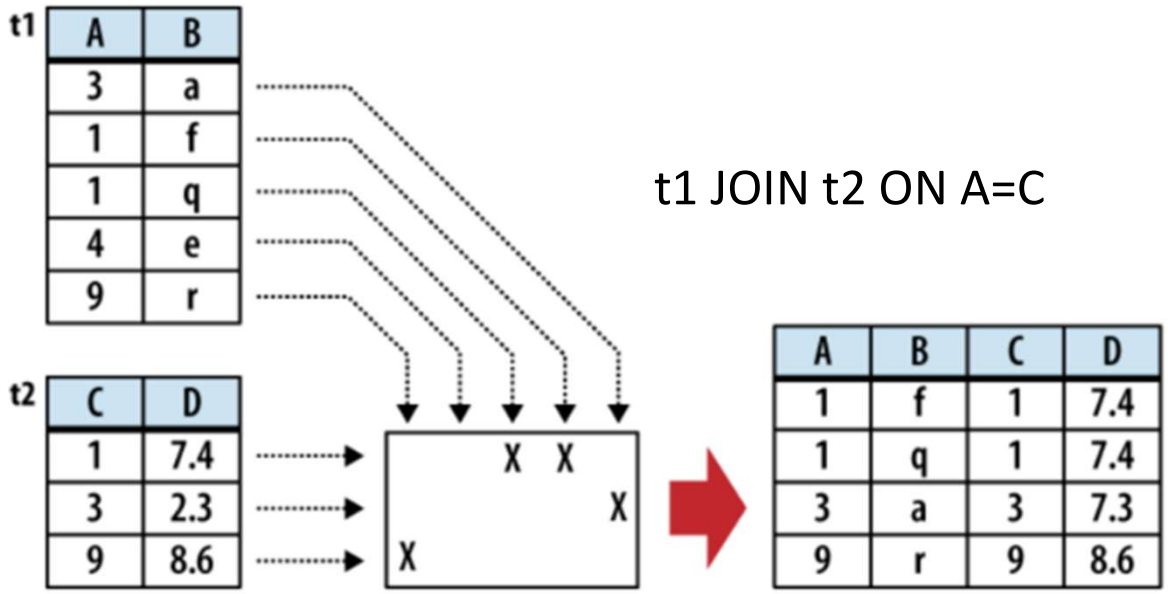
- Query example

select *name*, *title*
from (*student* **natural join** *takes*) **join** *course* **using** (*course_id*)



Join with On

- **“on”** specifies a predicate as a join condition
  - It allows join using columns that have different names



Join with On

- Query example

select *
from *student* **join** *project* **on** *ID* = *student_ID*

- Equivalent to:

select *
from *student, project* **where** *ID* = *student_ID*

student

ID	name
1	Alice
2	Bob
3	Charlie
4	David

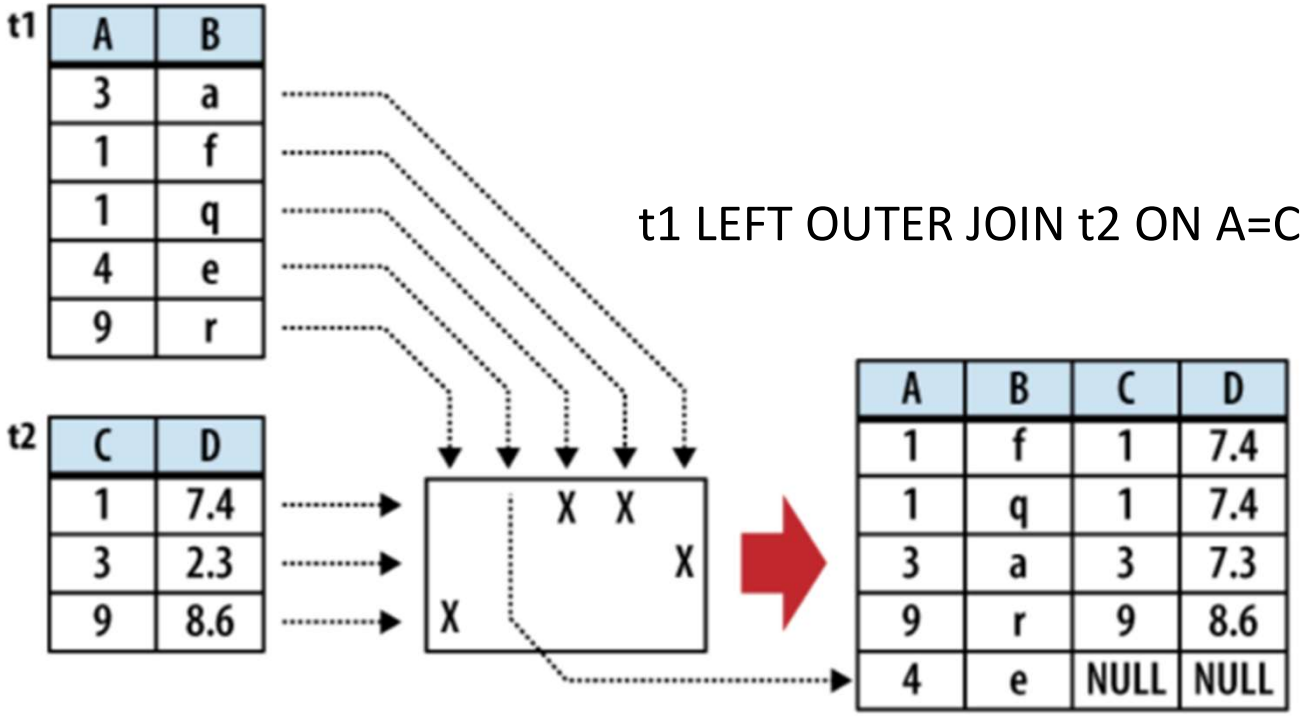
project

student_ID	project_ID
1	Prj1
3	Prj1
3	Prj2
5	Prj2

ID	name	student_ID	project_ID
1	Alice	1	Prj1
3	Charlie	3	Prj1
3	Charlie	3	Prj2

Outer Join

- Compute the join and then adds tuples that do not match any tuple
- Use *null* (unknown) values for missing attributes
- Three forms of outer join:
  - left outer join
  - right outer join
  - full outer join



Outer Join Examples

- Observe that

  student is missing student_ID 5

  project is missing student_ID 2 & 4

student

ID	name
1	Alice
2	Bob
3	Charlie
4	David

project

student_ID	project_ID
1	Prj1
3	Prj1
3	Prj2
5	Prj2

Left Outer Join

- Observe that

  student is missing student_ID 5

  project is missing student_ID 2 & 4

student

ID	name
1	Alice
2	Bob
3	Charlie
4	David

project

student_ID	project_ID
1	Prj1
3	Prj1
3	Prj2
5	Prj2

- *student* **left outer join** *project* **on** *ID=student_ID*

ID	name	student_ID	project_ID
1	Alice	1	Prj1
3	Charlie	3	Prj1
3	Charlie	3	Prj2
2	Bob	NULL	NULL
4	David	NULL	NULL

Natural Left Outer Join

- Observe that

  student is missing student_ID 5

  project is missing student_ID 2 & 4

student

ID	name
1	Alice
2	Bob
3	Charlie
4	David

project

ID	project_ID
1	Prj1
3	Prj1
3	Prj2
5	Prj2

- *student* **natural left outer join** *project*

ID	name	project_ID
1	Alice	Prj1
3	Charlie	Prj1
3	Charlie	Prj2
2	Bob	NULL
4	David	NULL

- In relational algebra:

  $student \bowtie project$

Right Outer Join

- Observe that

  student is missing student_ID 5

  project is missing student_ID 2 & 4

student

ID	name
1	Alice
2	Bob
3	Charlie
4	David

project

student_ID	project_ID
1	Prj1
3	Prj1
3	Prj2
5	Prj2

- *student* **right outer join** *project* **on** *ID=student_ID*

ID	name	student_ID	project_ID
1	Alice	1	Prj1
3	Charlie	3	Prj1
3	Charlie	3	Prj2
NULL	NULL	5	Prj2

Natural Right Outer Join

- Observe that

  student is missing student_ID 5

  project is missing student_ID 2 & 4

student

ID	name
1	Alice
2	Bob
3	Charlie
4	David

project

ID	project_ID
1	Prj1
3	Prj1
3	Prj2
5	Prj2

- *student* **natural right outer join** *project*

ID	name	project_ID
1	Alice	Prj1
3	Charlie	Prj1
3	Charlie	Prj2
5	NULL	Prj2

- In relational algebra:

  $student \bowtie project$

Full Outer Join

- Observe that

  student is missing student_ID 5

  project is missing student_ID 2 & 4

student

ID	name
1	Alice
2	Bob
3	Charlie
4	David

project

student_ID	project_ID
1	Prj1
3	Prj1
3	Prj2
5	Prj2

- *student* **full outer join** *project* **on** *ID=student_ID*

ID	name	student_ID	project_ID
1	Alice	1	Prj1
3	Charlie	3	Prj1
3	Charlie	3	Prj2
2	Bob	NULL	NULL
4	David	NULL	NULL
NULL	NULL	5	Prj2

Natural Full Outer Join

- Observe that

  student is missing student_ID 5

  project is missing student_ID 2 & 4

student

ID	name
1	Alice
2	Bob
3	Charlie
4	David

project

ID	project_ID
1	Prj1
3	Prj1
3	Prj2
5	Prj2

- *student* **natural full outer join** *project*

ID	name	project_ID
1	Alice	Prj1
3	Charlie	Prj1
3	Charlie	Prj2
2	Bob	NULL
4	David	NULL
5	NULL	Prj2

- In relational algebra:

  $student \bowtie project$

Join Conditions and Types

- **Join condition** – Natural vs. On vs. Using
  - defines how to match tuples
- **Join type** – Inner Join vs. {Left/Right/Full} Outer Join
  - defines how tuples that do not match any tuple in the other relation are treated.

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

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

Join Conditions and Types – More Examples

Relation *course*

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

Relation *prereq*

course_id	*prereq_id*
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

- *course* **natural right outer join** *prereq*

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

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

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

Join Conditions and Types – More Examples

Relation *course*

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

Relation *prereq*

course_id	*prereq_id*
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

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

course_id	*title*	*dept_name*	*credits*	*prereq_id*	*course_id*
BIO-301	Genetics	Biology	4	BIO-101	BIO-301
CS-190	Game Design	Comp. Sci.	4	CS-101	CS-190

- *course* **left outer join** *prereq* **on** *course.course_id = prereq.course_id*

course_id	*title*	*dept_name*	*credits*	*prereq_id*	*course_id*
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	*null*	*null*

Join Conditions and Types – More Examples

Relation *course*

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

Relation *prereq*

course_id	*prereq_id*
BIO-301	BIO-101
CS-190	CS-101
CS-347	CS-101

- *course* **natural right outer join** *prereq*

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

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

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

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- Join Expressions
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View

- In some cases, not all users should see the entire table.
- A **view** provides a way of hiding certain data
- A view is defined as follows:

  create view *view_name* **as** <*select statement*>

  - E.g. Let's create a view of instructors without their salary
    - Certain users do not need to know the salary.

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

faculty (logical view)

ID	name	dept_name
1	Alice	Comp. Sci.
2	Bob	Biology

Instructor (physical table)

ID	name	dept_name	salary
1	Alice	Comp. Sci.	20000
2	Bob	Biology	10000

View Examples

- Let's create a view of all instructors in the Biology department

```
create view bio_faculty as
  select name
  from faculty
  where dept_name = 'Biology'
```

- Note: One view may be used in the expression defining another view

- Expand the view :

```
select *
  from bio_faculty
where name like '%dar%';
```

- To

```
select *
    from (select name
            from faculty
          where dept_name = 'Biology')
  where name like '%dar%';
```

Note#1: A view is purely logical; it is not a real table that stores data. Instead, it stores only the definition (i.e., the SELECT statement).

Note#2: Materialized views can be physically stored on disks

Update of a View

- Let's add a new tuple to *faculty* view which we defined earlier

  insert into *faculty*

  values ('3', 'Charlie', 'Music');

faculty view (logical)

ID	name	dept_name
1	Alice	Comp. Sci.
2	Bob	Biology

  - This inserts into *instructor (ID, name, dept_name, salary)*
  - Must have a value for salary.

Instructor (physical table)

ID	name	dept_name	salary
1	Alice	Comp. Sci.	20000
2	Bob	Biology	10000
3	Charlie	Music	????

- Two approaches
  1. Reject the insert
  2. Insert the tuple

     ('3', 'Charlie', 'Music', null)

     into the *instructor* relation

Note: PostgreSQL uses NULL

Some Updates Cannot be Translated Uniquely

instructor

ID	name	dept_name	salary
1	Alice	Comp. Sci.	20,000
2	Bob	Biology	10,000

department

dept_name	building
Comp. Sci.	Taylor
Biology	Taylor
Elec. Eng.	Watson

- **create view** *instructor_info* **as**
  select *ID, name, building, budget*
  from *instructor* **natural join** *department;*

instructor_info (logical view)

ID	name	building
1	Alice	Taylor
2	Bob	Taylor

- **insert into** *instructor_info*
  values (‘4', ‘David', ‘Watson’);
- Issue
  - Which department? Is EE dept is the only one in Watson?

And Some Updates Should Not Be Allowed 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?*

If we allow the insertion, the tuple will not appear in the view

View Updates in SQL

- Most DBMSs allow updates only on simple views
  - The **from** clause has only one database relation.
  - The **select** clause does not have any WHERE predicates, aggregates, or **distinct** specification.
  - The query does not have a **group by** or **having** clause.
  - Attributes not listed in the **select** clause can be set to null

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Transactions

- A **transaction** consists of a sequence of SQL statements but is an atomic work

```
BEGIN;
insert into student (ID, name) values ('10', 'Ellie');
insert into takes (student_id, course_id) values ('10', 'swe3003');
COMMIT;  -- or ROLLBACK;
```

  - Two insert statements will be either fully executed or rolled back as if both never occurred

- Isolation from concurrent transactions
  - More details in Chapter 17.

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Integrity Constraints

- Integrity constraints protect databases
  - E.g.)
    - A bank account must have a balance greater than $0.00
    - A customer must have a (non-null) phone number
    - Minimum hourly wage is KRW 9,620
    - New legal cap on weekly work hours is 69
    - Etc.

Constraints on a Single Relation

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

Not Null Constraints

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

    name **varchar**(20) **not null**
    budget **numeric**(12,2) **not null**

Unique Constraints

- Candidate key is a set of attributes that uniquely identifies each record in the table.
- **unique** (A_1, A_2, …, A_m)
  - Attributes (A_1, A_2, …, A_m) of a tuple must be unique
  - Candidate keys are permitted to be null (in contrast to primary keys)
    - NULL is never equal to other NULL values
    - NULL is not considered a duplicate value
- **primary key** (A_1, A_2, …, A_m)
  - Primary key is the chosen candidate key.
  - It cannot have NULL (unknown) values.

Check Constraints

- **check** (P) specifies a predicate P that must be satisfied.
- 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

- A value that appears in one relation must appear in another relation.
  - **Foreign** key is the primary key of another relation S.
  - Any values in foreign key A of R must appear in S.

- Example: If a customer ID appears in in the *Order* relation, there must be a tuple in the *customer* relation for the customer ID.
  - DBMS rejects insert queries that violate referential integrity.
    - E.g., **insert into** order **values**('4', 'invalid_id', 346); -- reject

Foreign Key

order_ID	customer_ID	item_ID
1	ByteBoi	224
2	FizzBug	356
3	FizzBug	128

Order Table

Primary Key

customer_ID	name	address
ByteBoi	Bob	… Suwon, KR
FizzBug	Charlie	… Seoul, KR

Customer Table

Referential Integrity (Cont.)

- Referential integrity is enforced via Foreign key constraint

- Foreign *keys are* specified in SQL **create table** statement

  foreign key (*customer_ID*) **references** *customer*

  - By default, a foreign key references the primary-key of the referenced table.

- SQL allows a list of attributes of the referenced relation to be specified explicitly.

  foreign key (*cust_name*)
  references *customer*(*customer_name*)

Cascading Actions in Referential Integrity

- In case of delete or update, cascade the action

```
create table order (
(…
   customer_ID varchar(20),
   foreign key (customer_ID) references customer
        on delete cascade
        on update cascade,
  …)
```

Order

order_ID	customer_ID	item_ID
1	ByteBoi	224
2	FizzBug	356
3	FizzBug	128

Customer

customer_ID	name	address
ByteBoi	Bob	… Suwon, KR
FizzBug	Charlie	… Seoul, KR

```
delete customer where customer_ID = 'FizzBug';
```

- If a customer tuple is deleted/updated, corresponding order tuples are deleted/updated.

Cascading Actions in Referential Integrity

- In case of delete or update, cascade the action

```
create table order (
(…
   customer_ID varchar(20),
   foreign key (customer_ID) references customer
        on delete cascade
        on update cascade,
  …)
```

Order

order_ID	customer_ID	item_ID
1	ByteBoi	224

Customer

customer_ID	name	address
ByteBoi	Bob	… Suwon, KR

```
delete customer where customer_ID = 'FizzBug';
```

- If a customer tuple is deleted/updated, corresponding order tuples are deleted/updated.

Cascading Actions in Referential Integrity

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

create table *order* (
(…
customer_ID **varchar**(20) **default** ‘pending’,
foreign key (*customer_ID*) **references** *customer*
on delete set default, -- or **on delete set null**
…)

- E.g., **delete** customer **where** customer_ID = ‘FizzBug’;

Order

order_ID	customer_ID	item_ID
1	ByteBoi	224
2	FizzBug	356
3	FizzBug	128

Customer

customer_ID	name	address
ByteBoi	Bob	… Suwon, KR
FizzBug	Charlie	… Seoul, KR

Cascading Actions in Referential Integrity

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

create table *order* (
(…
customer_ID **varchar**(20) **default** ‘pending’,
foreign key (*customer_ID*) **references** *customer*
on delete set default, -- or **on delete set null**
…)

- E.g., **delete** customer **where** customer_ID = ‘FizzBug’;

Order

order_ID	customer_ID	item_ID
1	ByteBoi	224
2	pending	356
3	pending	128

Customer

customer_ID	name	address
ByteBoi	Bob	… Suwon, KR

Integrity Constraint Violation During Transactions

- Consider:

```
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?
  - Set father and mother to **null** (unknown) initially
    - The first ancestor must have NULL in father and mother

Complex Check Conditions

- The predicate in the check clause can include a subquery.

```
create table section (
        ...
        time slot id varchar (4),
         ...
        check (time_slot_id  in
                (select time_slot_id from time_slot)
          ))
```

  - The condition is checked when a tuple is inserted or modified in *section*, also when the relation *time_slot* changes

Assertions

- An **assertion** is a predicate expressing a condition that the database must satisfy.
- An assertion in SQL takes the form:

  create assertion <assertion-name> **check** (<predicate>);

- Example assertions:
  - An instructor cannot teach in two different classrooms in a semester in the same time slot

```
create assertion no_double_booking
check (
   not exists (
      select 1
      from schedule s1 join schedule s2 using (instructor_id)
      where s1.classroom_id != s2.classroom_id
          and s1.time_slot = s2.time_slot
   ));
```

- Note: Unfortunately, no DBMS supports assertions despite it is in SQL standard specification

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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

Large-Object Types

- Large objects (KB, MB, GB) are stored as :
  - **blob**: binary large object (e.g., photos, videos, etc)
  - **clob**: character large object (e.g., large text files)

- When a query returns a large object, a pointer is returned rather than the large object itself.

User-Defined Types

- **create type** creates user-defined type

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

- Example:

  create table *department*
  (*dept_name* **varchar** (20),
  building **varchar** (15),
  budget *Dollars*);

Domains

- **create domain** 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.

- Example:

  create domain *degree_level* **varchar**(10)
  constraint *degree_level_test*
  check (**value in** ('Bachelors', 'Masters', 'Doctorate'));

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- Index Definition in SQL
- Authorization

Index Creation

- Many queries reference only a small proportion of the records in a table.
- It is inefficient for the system to scan the entire relation to find a record with particular value
- An **index** is a data structure that allows DBMS to find tuples efficiently (e.g., B+tree, Hash Table).
- We create an index with the **create index** command

  create index <name> **on** <relation-name> (attribute);

Index Creation Example

- **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*) -- B+tree
- **create index** *studentID_index* **on** *student* **using HASH** (*ID*) -- Hash

- The query:

  select *
  from *student*
  where *ID* = '12345'

  will use the index and return the output relation faster

Outline

- Join Expressions
- Views
- Transactions
- Integrity Constraints
- SQL Data Types and Schemas
- Index Definition in SQL
- Authorization

Authorization

- all, none, or a combination of the following privileges on a relation or a view can be authorized.
  - **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.

Authorization Specification in SQL

- The **grant** statement is used to grant 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 all privileges on** *department* **to** db_user1, db_user2

- Granting a privilege on a view does not imply granting any privileges on the underlying relations.

Privilege List

- **select**: allows read access to relation, or the ability to query using the view
  - Example: grant users *db_user1 and db_user2* **select** authorization on the *department* relation:

    grant select on *department* **to** *db_user1, db_user2*

- **insert**: the ability to insert tuples
- **update**: the ability to update using the SQL update statement
- **delete**: the ability to delete tuples.
- **all privileges**: all the allowable privileges

Revoking Authorization

- 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 <user list> includes **public,** all users lose the privilege except those granted it explicitly.