

CP363: Database I

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Chapter 1: Introduction

1 Database Management Systems (DBMS)

A *DBMS* is a collection of software to enable a user to create, maintain and utilize a DB (Ex. Oracle, MySQL, etc).

1.1 Advantages of DBMS

- Efficient data access
- Data integrity and security
- Data administration
- Data independence
- Concurrent processing crash recovery
- Reduce application development time and cost

Concurrent Processing

{figure out diagram}

2 Logical Schema of a Database

- Schema is the data structure IBM had the hierarchical model, other companies created the Network and Lodeysol models
- Logical (conceptual) scheme is the logical data structure

3 Physical Schema

- How data is stored physically: tree, heap, etc
- View on the logical schema, different ways of viewing data; sometimes public facing

4 Logical Data Independence

- Changing to logical schema will not effect the view on it

5 Physical Data Independence

- Changing to physical schema will not effect the logical schema

5.1 Lingo

{figure out diagram}

6 Data Models

- IBM had the hierarchical model, other companies created the Network and Lodeysol models

Chapter 2: Introduction to the Relational model

1 Relational DB Model

- Data is stored using tables, also known as relations
- Each column has a name, AKA attribute
- Each row is record

1.1 Schema

- Defining the structure of a relation

Example 1.

```
student_table(Id int(8),
              Name varchar(8),
              Major varchar(8),
              GPA float);
```

- Tables are defined as such: $R(A_1, \dots, A_n)$
- An *instance* is a record in a table

A **database instance** is all the data in the DB. **Database schema** contains schemas for all tables in the form $S = R_1, \dots, R_m$.

The table must satisfy four constraints:

1. Domain constraint
2. Key integrity constraint
3. Entity integrity constraint
4. Referential integrity constraint

Example 2.

Eid	Name	Dependent
1234	Tom	Mary
1234	Tom	Peter
2345	John	Tim
2345	John	Jane
3456	David	Jim

Remember **NO** duplicates. Instead change those records to:

Eid	Name	Dependent
1234	Tom	Mary, Peter
2345	John	Tim, Jane
3456	David	Jim

Each attribute can only contain *atomic* values. Ex. Cannot contain a set of values. FFS, do this:

Eid	Name	Dependent 1	Dependent 2
1234	Tom	Mary	Peter
2345	John	Tim	Jane
3456	David	Jim	--

This is also **NOT** ideal.

R_1 :

Eid	Name
1234	Tom
2345	John
3456	David

R_2 :

Eid	Dependent
1234	Mary
1234	Peter
2345	Tim
2345	Jane
3456	Jim

1. Key Integrity Constraint

- Observation: No tuples in a table are the same; in other words, every tuple in a table needs to be unique..SO DONT STORE RECORDS TWICE
- \Rightarrow Each record, tuple, can be <u>uniquely identified</u> by a certain set of attributes
- The *super key* is a set of attributes that can uniquely identify a record (tuple)
- The trivial super key is the one with all the attributes
- A minimal super key is called a *candidate key*
- A candidate key be picked as the *primary key* \rightarrow Refer to next Example 3
- Every relation must have a primary key `student_table(Id,Name,Major,GPA)` where `Id` is the primary key

Example 3. `id,dept_name` are super keys but not candidate keys. But two candidate keys are `id,Name` as they are unique. Then pick on candidate to be the primary, this `Id` will be picked as the primary key.

Example 4. {table}

We have the minimal super key = candidate key. $\{A, D\}$ is not a super key. $\{B, C\}$ is a super key. Is it a candidate key? No, thus, C is a super key $\Rightarrow C$ is a candidate key $\Rightarrow C$ is a primary key

2. Entity Integrity Constraint

- The primary key cannot be `null`; in our example, that means `Id` cannot be `null`
- The rest of the attribute can be `null`

3. Referential Integrity Constraint

- A *foreign key* must either contain a `null` value or a value in the **referenced key**

Example 5. Back to the example with R_1 and R_2 . We have $R_1(\text{Eid}, \text{Name})$ and $R_2(\text{Eid}, \text{Dependent})$.

Thus, Eid , is an foreign key in R_2 because Eid is the primary key in R_1 . Eid in R_1 is the referenced key.

Chapter 7: DB Design

1. Requirement Analysis

- Data to be stored
- Applications
- Performance analysis

Example 6. Registration system

student records
class records
professor records

Actions:

- To register a student in the class
- Print class list
- Print professor schedule

2. Conceptual Database Design

- Entity-Relationship model (ER model)
- Entity is equivalent to record type
- The relationship between entities

3. Logical Database Design

- Convert the ER model into a relational model (ie. convert to tables - relations)

4. Scheme Refinement

- Theory of relational database - 1st, 2nd, 3rd, 4th BC (Boyce-Codd) normal forms

5. “Physical” Database Design

- Add index files to speed up certain applications

6. Application and Security Design

1 Entity-Relationship Model

Entity \equiv record

- An entity is an object in the real world that is distinguishable from other objects

- A **diamond** indicates a relationship between two entities
- A **triangle** indicates a subclass of
- A **circle** represents an attribute
- A **rectangle** represents an entity

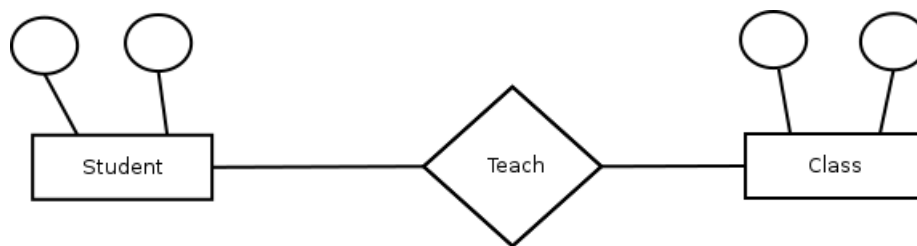
Example 7. A student record

These are attributes

Id	Name	GPA	Major
----	------	-----	-------

- An entity is a collection of entities of the same type
- All entities in the same set have the same attributes (circles)
- *Student* is the entity and $\{Id, Name, GPA, Major\}$ are the attributes (circles)
- Each entity has a primary key
- The key should depend on a real life situation and not the current set of data

2 Relationship Between Entities



2.1 Many to Many Relationship

1. A student can take many courses
2. A class can have many students

2.2 1 to Many Relationship

1. A professor can teach many classes
2. A class is taught by 1 professor

2.3 1 to 1 Relationship

1. A department has only one chair
2. A professor is the chair of only one department

Note: Every entity has a key and every relationship has a key.

A relationship does not have to be binary.

2.4 Total Participation

- Everyone is involved \Rightarrow total participation (**thick line**)

2.5 Recursive Relationship

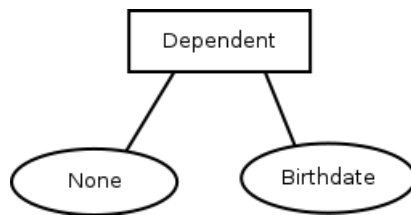
- An entity can only appear once in a design
- The key for the relationship (*Id*) - in our example

2.6 Weak Entity

- Entity without superkey

Note: Thick [box] lines implies weak entity.

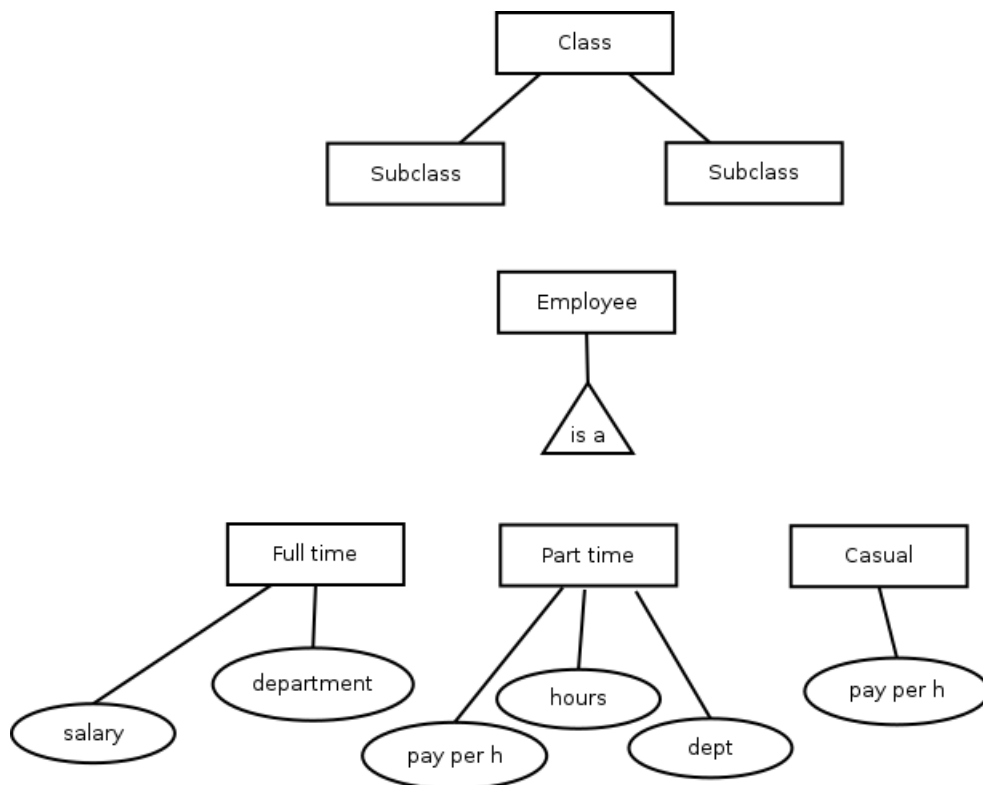
Example 8.



2.7 Strong Entity

- Entity with a super key (primary key)
- Everything so far is a strong entity

3 Class Hierarchies



The subclasses are disjoint.

4 Aggregation

- Abstraction to group relationships

Refer to customer - borrower - loan.

5 Issues in Conceptual Design Using the ER Model

1. Should a concept be modeled as an attribute or as an entity
 - Refer to employee one
 - Employees can have multiple addresses (sub address with employee to create new entity with attributes)
 - If we wanted to conduct searches in the address - it would be easier with address as an entity (ex. search for a city within a country)
 - Refer to picture - it is wrong, solution: look to next picture (make from and to as entity instead of attribute)

6 ER to Relational Database Mapping

Step 1

For each strong entity set, E , create a table (relation), R , that includes all attributes of E . The key for the entity will be the key for the table (relation).

strong entity \Rightarrow table

Step 2

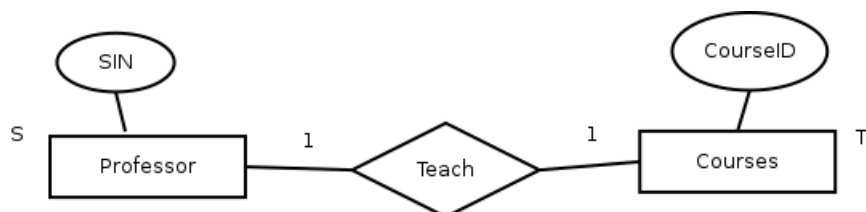
For each weak entity set, W , create a table, R , that includes all attributes of W and include it as a foreign key, the primary key of the owner entity. The key for the relation is the partial key and the key of the own entity.

{table for employee-dependents}

Step 3

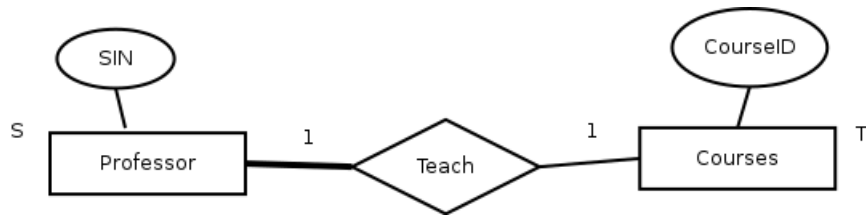
For each 1:1 relationship between two strong entities, S and T . **No** new table (relation) is required. Just add the primary key of S as a foreign key in T .

Example 9.



professor(SIN, ..., ...)
courses(courseID, ..., ..., SIN)

If total participation exists in \underline{S} , we should add the primary key of T as a foreign key to \underline{S} .



Every professor much teach one course and the course cannot be taught by more than one professor.

Step 4

For each 1: n relationship between two strong entities S and T . No new table is required. Just add the primary key of S as a foreign key in T .

Example 10.

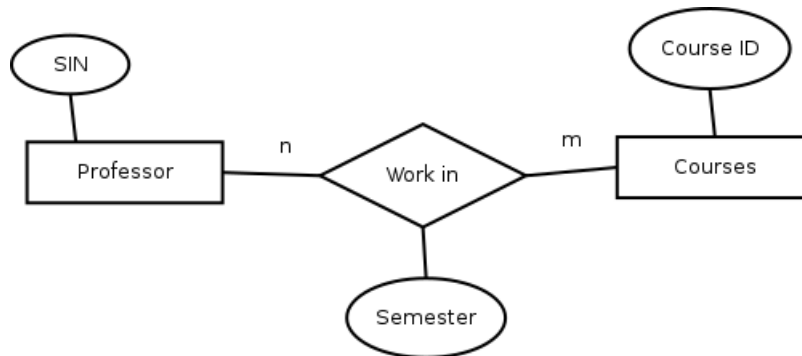


Employee(id, ..., ..., departmentID)

Step 5

For each many to many relationship between S and T , create a new table (relation) that contains the primary key of S and T . The key for the new table is the primary key of both S and T together.

Example 11.

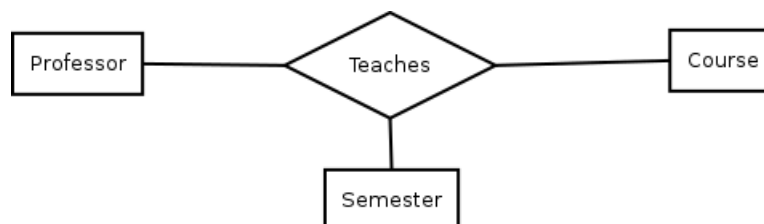


Teaches(SIN, CourseID, semester)

Step 6

n -ary relationships.

Example 12.

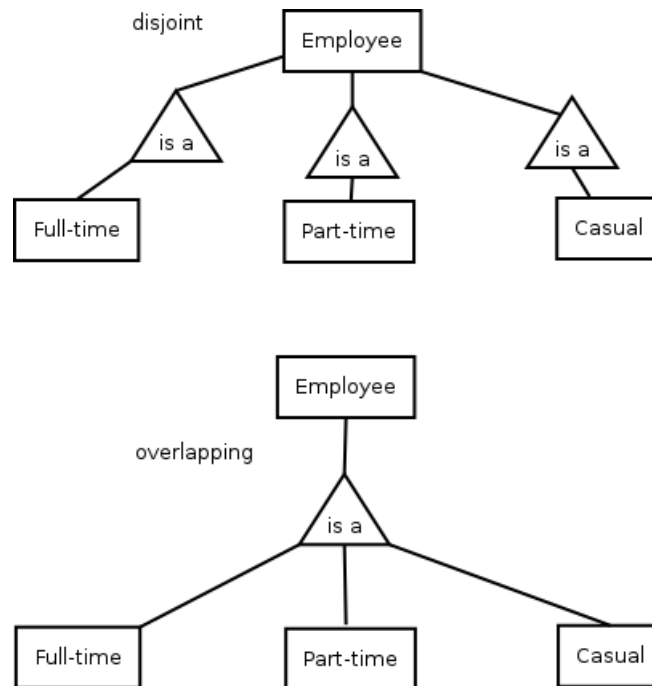


Teaches(SIN, semester_id, course_no)

Create a new table that contains the primary key of all the entities. The keys for the table are the primary keys of all entities together.

Step 7

Translating class hierarchies.



Disjoint implies that we create a table for each disjoint entity and it is necessary to create one for the parent. **Overlapping** implies that we create a table for all overlapping entities and create a table for the parent; only put the key of the parent in table of the subclass.

Step 8

Aggregates.

Create a table for an aggregate that contains the key for the aggregate and the key for the entity.

Example 13.

Supervise(SIN,Graduate_SIN, p_no) all with dotted underlines

7 Data Definition Language (DDL) - part of SQL

Example 14. Create a table in SQL

Employee(Eid,name,address,salary,Supervisor) - last one is dotted
Supervisor(Eid, S_ID) both dotted

Here's the code:

```
CREATE TABLE Employee
```

```

(Eid          integer(9),      // or int(9)
 Name         varchar(30),
 address      varchar(50),
 salary       integer(5) unique, // CANNOT BE null
 Sid          integer(9),
 primary key  (Eid)
 foreign key  (SupervisorID) reference (Employee))

```

```

CREATE TABLE Supervisor
(Eid          int(9),
 Sid          int(9),
 primary key  (Eid,Sid),
 foreign key  (Eid) reference (Employee),
 foreign key  (Sid) reference (Employee))

```

7.1 Delete a Table

```
drop table Employee
```

7.2 Update a Table

Using Employee table, we want to add a new attribute.

```
Alter table Employee
    add status varchar(6)
```

Now we want to delete an attribute:

```
Alter table Employee
    drop name
```

We now want to delete a record with: Employee id=1234. Employee with id=1234 may be a supervisor of other Employee's. We need to update every other Employee's Supervisor.

Chapter 7: Relation Algebra

1 Basic Operation

Select	σ (lowercase sigma)
Project	Π
Union	\cup
Set different	$-$
Cartesian product	\times
Rename	ρ

The first 3 +last are unary operations and the last three are binary operations.

Example 15. Employee(Id,name,address,dept,salary)

```
Temp  $\leftarrow \Pi$  EmployeeId,name
```

Just choose a number of attributes from the table.

Select all records with a salary of ≥ 80000

```
R  $\leftarrow \sigma$  Employeesalary $\geq 80000$ 
```

Π Employee_{Id,none} (Select Employee_{salary} \geq 80000)

```

 $\varnothing$       Id,name
From      Employee
Where     salary  $\geq$  80000

```

Union is the same as set union. Set difference: only operands (relations) with the same attributes can be involved.

1.1 Cartesian Product

```

Employee(Id,name,dept,...)
Dept(dept_no,name,...)

```

```

Employee
1  1234    Tom    2    ...
2  2345    Mary   1    ...
3  3456    Jim    1    ...
4  4567    Kate   2    ...

```

```

Dept
a  1      Sales    ...
b  2      Accounting ...

```

Where this will produce a new table.

The universal relation contains all attributes. In order to avoid duplicates, we break it into many smaller relationships. We can use the cartesian product to join them back together. Unfortunately, joining them back together doesn't always work 100%.

1.2 Join Product

- Natural join
- Equivalent join
- Conditional join

Natural join: \bowtie . Example, Employee \bowtie Department

1. Employee \times Department
2. $\sigma_{\text{Employee.Dnum} = \text{Dnum}}$

Equi-Join

$$\begin{aligned} & \text{Employee}_{\text{dnum}} \bowtie \text{Department} \\ \equiv & \sigma_{\text{Dnum}} \text{Employee} \times \text{Department} \end{aligned}$$

Conditional Join

$$\begin{aligned} & \text{Employee} \bowtie \text{Department} \\ & E_1 \text{ salary} > E_2 \text{ salary} \\ \equiv & \sigma_{E_1 \text{ salary} > E_2 \text{ salary}} E_1 \times E_2 \end{aligned}$$

Example 16.

Sailors(Sid, Sname, age)

Boat(Bid, Bname, colour)

Reserves(Sid, Bid, Date)

Query 1

Find the name of the sailors who have reserved boat with Bid=103.

$$\begin{aligned}
 T_1 &\leftarrow \text{Sailor} \bowtie \text{Reserves} \\
 T_2 &\leftarrow \sigma_{\text{Bid}=103} T_1 \\
 T_3 &\leftarrow \Pi_{\text{Sname}} T_2 \\
 T_3 &\leftarrow \Pi_{\text{Sname}}(\text{Sailor} \bowtie (\sigma_{\text{Bid}=103} \text{Reserves}))
 \end{aligned}$$

Query 2

Find the names of the sailors who have reserved at least one **red** boat.

$$\begin{aligned}
 T_1 &\leftarrow \text{Sailor} \bowtie \text{Reserves} \bowtie \text{Boat} \\
 T_2 &\leftarrow \sigma_{\text{colour}=\text{red}} T_1 \\
 T_3 &\leftarrow \Pi_{\text{Sname}} T_2 \\
 T_1 &\leftarrow \Pi_{\text{Sname}}(\text{Sailor} \bowtie \text{Reserves} \bowtie (\sigma_{\text{colour}=\text{red}} \text{Boat}))
 \end{aligned}$$

Query 3

Find the names of the sailors who have reserved at least a **red** or a **green** boat.

Note: You can use red or green in one line, but it only works for *or*. You cannot do a similar operation with *and*. But it is preferred to split it up.

$$\begin{aligned}
 \text{Red} &\leftarrow \Pi_{\text{Sname}}(\text{Sailor} \bowtie \text{Reserves} \bowtie (\sigma_{\text{colour}=\text{red}} \text{Boat})) \\
 \text{Green} &\leftarrow \Pi_{\text{Sname}}(\text{Sailor} \bowtie \text{Reserves} \bowtie (\sigma_{\text{colour}=\text{green}} \text{Boat})) \\
 \text{Answer} &\leftarrow \text{Red} \cup \text{Green}
 \end{aligned}$$

Query 4

Find the names of the sailors who have reserved at least a **red** *and* a **green** boat.

$$\text{Answer} \leftarrow \text{Red} \cap \text{Green}$$

Query 5

Find the name of sailors who have reserved **all** red boats.

$$\begin{aligned}
 \text{All the red boats} &\leftarrow \sigma_{\text{colour}=\text{red}} \text{Boats} \\
 T &\leftarrow \Pi_{\text{Sname}}(\text{Sailor} \bowtie \text{Reserves} / \text{All red}) \\
 &\text{or} \\
 T_1 &\leftarrow \Pi_{\text{Sid}, \text{Bid}}(\text{Sailors} \times \text{All red}) \\
 T_2 &\leftarrow T_1 - \Pi_{\text{Sid}, \text{Bid}}(\text{Reserves}) \\
 T_3 &\leftarrow \Pi_{\text{Sid}}(\text{Sailors}) - \Pi_{\text{Sid}}(T_2)
 \end{aligned}$$

Division

Note: This is a not a basic operation, shame.

A	x	y
α	1	
α	2	
α	3	
β	1	
γ	1	
θ	1	
θ	3	
θ	4	
ϵ	1	
ϵ	2	
κ	1	
κ	2	
κ	3	

Where A and B are the same attribute.

B	y
	1
	2

$\frac{A}{B}$	x
	α
	ϵ
	κ

First test: chapter 1 (1.1-1.5), chapter 2 (2.1-2.4), chapter 3 (3.2), chapter 7, chapter 6 (6.1).

Example 17. `Employee(id, name, dept, ..., salary)`

We need to find the total salary of all employees.

1. Retrieve all employee records
2. Write a program to sum all salaries

Denote \mathcal{G} as an aggregate function (sum, average, max, min, count)

Thus, grab all salaries of employees: $\mathcal{G}_{\text{sum(salary)}}\text{Employee}$.

Find the number of records per `Employee`: $\mathcal{G}_{\text{count(*)}}\text{Employee}$

Example 18. `Employee(id, name, dept, ..., salary)`

We want to find the total salary for each department.

$\text{dept}\mathcal{G}_{\text{sum(salary)}}\text{Employee}$

Maximum salary for each dept:

$\text{dept}\mathcal{G}_{\text{sum(salary)}}\text{Employee}$

Find the average salary:

$\text{dept} \mathcal{G}_{\text{avg}(\text{salary})} \text{ as averageEmployee}$

Note: We created an alias for `avg`, that is `average`. Thus calling it will invoke `avg`.

Count the number of employees in each dept:

$\text{dept} \mathcal{G}_{\text{count}(\text{id})} \text{Employee}$

Outer Join

There are 3 types:

1. Full outer join *bowtie with both top and bottom lines extended*
2. Left outer join *bowtie with left top and bottom lines extended
3. Right outer join *bowtie with right top and bottom lines extended*

Project Π
Selection σ

In SQL:

Select <attribute1> ... <attribute n>
From <relation1> ... <relation n>

Example 19.

$\Pi_{a_2, a_3}(R_{1R_1a_1=R_2a_2} \bowtie R_{2R_2a_4=R_3a_4} \bowtie R_3)$

Translation:

Select a2,a3
From R1, R2, R3
where R1a1 = R2a2 and R2a4 = R3a4

$\mathcal{G}_{\text{sum}(a_1)} R_1$

Translation:

Select sum(a1)
From R1

Find the sum for each dept:

$\text{dept} \mathcal{G}_{\text{sum}(\text{salary})} R_1$

Translation:

Select sum(salary) as dept_total
From R1
Group by dept

You can also group would qualify having {some condition}.

1.3 Set Operations

- Union
- Intersect
- Minus/except

We **cannot** check if something is or isn't in a set (set membership test). We also **cannot** check if something exists or not (existence test).

Example 20. Employee(Id, name, dept, dept_location, salary)

```
Select    sum(salary) as dept_total
From      Employee
Group     by dept
```

$$\equiv \text{dept} \mathcal{G}_{\text{sum(salary)}} \text{Employee}$$

Example 21. Given these three tables:

Sailors(Sid, name, rating, age)

Boats(Bid, name, colour)

Reserves(foreign: Sid, foreign: Bid, date)

Find the name of the sailor who has reserved boat with Bid=103.

```
Select    name
From      Sailors S, Reserved R
where     Bid=103 and S.sid=R.sid
```

Find the Sid's of sailors who reserved a red boat.

```
Select    Sid
From      Boats B, Reserved R
where     B.bid=R.bid and colour='red'
```

```
Select    name
From      Sailor S, Boats B, Reserved R
where     S.sid=R.sid and B.bid=R.bid and colour='red'
```

Find the colour's of boats reserved by Tom.

```
Select    code
From      Sailor S, Boats B, Reserved R
where     S.sid=R.sid and B.bid=R.bid and S.name='Tom'
```

Find the color of boats reserved by a sailor where name starts with a 'T'. We use something like this:

```
S.name    like 'T%'
```

where % is 0 to any arbitrary characters - a wildcard.

Find the name of the of sailors who have reserved a red boat but NOT a green boat.

```
SELECT      name
FROM        Sailors S, Boats B, Reserved R
WHERE       S.sid=R.bid and
            B.bid=R.bid and
            colour='red'
```

minus (or except)

```
SELECT      name
FROM        Sailors S, Boats B, Reserved R
WHERE       S.sid=R.bid and
            B.bid=R.bid and
            colour='green'
```

Find the name of a sailor who has reserved a boat with bid=103.

```
SELECT      name
FROM        Sailor S
WHERE       S.sid IN
            (SELECT      Sid
             FROM        Reserved
             WHERE       bid=103)
```

Set Comparison Operators:

- Any
- ALL
- Some
- Every

To be used with $>$, $<$, \leq , \geq , \neq .

Example 22. Find the same of sailors whose rating is greater than some sailor called Tom.

```
SELECT      name
FROM        Sailor S
WHERE       S.rating > Any
            ( SELECT      S2.rating
              FROM        Sailor S2
              WHERE       S2.name = 'Tom' ) // also S2.name like 'T%'
```

Example 23. Find sailors who have reserved all the boats.

```
SELECT      B.bid
FROM        Boats B

SELECT      R.bid
FROM        Reserves R
WHERE       R.sid=S.sid
```


Example 24. Find the name of the oldest sailor:

- This is 2 steps:
 - Find the oldest sailor
 - Find the name of the oldest sailor

```
SELECT      name
FROM        Sailor

WHERE       age=(SELECT      max(age)
                        FROM        Sailor)
```

1.4 Null Values

- Aggregate functions \rightarrow ignore null values
- Null \Rightarrow unknown

Three Value Logic:

- True, False, unknown
- OR
 - T or unknown \Rightarrow True
 - False or unknown \Rightarrow unknown
 - unknown or unknown \Rightarrow unknown
- AND
 - T and unknown \Rightarrow unknown
 - False and unknown \Rightarrow False
 - unknown and unknown \Rightarrow unknown
- NOT
 - Not(unknown) \Rightarrow unknown

Example 25. Full, left, right outer joins

Sailors				Reserves		
Sid	name	rating	age	Sid	bid	date
22	Tom	7	22	22	30	10/10/15
31	John	10	15	31	40	10/11/15
58	Peter	7	40	32	50	12/11/15

Then:

```
Select      S.sid, R.bid
From        Sailors S {natural left outer join} Reserves R
```

The result:

22	30
31	40
22	50
58	null

1.5 Updating Tables

Example 26.

Update	Employee
Set	name='Tom'
Where	eid=1234

Options:

1. Restrict \rightarrow default
2. Cascade
3. Set default
4. Set null