3005 Final Full Notes

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Contents

1 Definitions

1.1 Database Terms

- **Database**
  - a collection of related data stored on a computer
- **Data**
  - a value which represents known facts with an implicit meaning
- **Mini world**
  - some part of the real world which is represented by the data stored in the database
- **Database management system** (DBMS)
  - software to facilitate creation and maintenance of a database
- **Database system**
  - database and…
  - the application programs developed on top of the DBMS

1.2 Actors

1.2.1 Behind the Scenes

- **System designer**
  - design and implement DBMS modules
- **Tool developer**
  - design and implement tools
    * modeling
    * designing
    * performance monitoring
    * prototyping
    * test data generation
    * UI creation
    * simulation
- **Operator and maintenance personnel**
  - tunnel rats
  - manage the running and maintenance of the DB

1.2.2 On the Scene

- **DBA** (database administrator)
  - acquire software and hardware resources
  - control the use of those resources
  - monitor efficiency
  - monitor use of DB
  - authorize access to DB
- **DB designer**
  - define the following aspects of a DB:
    * structure
    * constraints
    * content
    * transactions
  - must understand end users' needs
- **System analyst**
  - design applications and canned transactions for a DB

- **Application developer**
  - implement the specifications developed by analysts
- **End user**
  - use DB day-to-day
  - don't know or care how DB is structured
  - two categories:
    - naïve users
    - business analysts

1.3 Data Models

- **Data model**
  - way of representing data in a meaningful way
  - how data is *structured* and *operated*
  - three parts:
    - concepts to describe structure
    - operations for manipulating structures
    - constraints which must be obeyed
  - **entity relationship model**
    - entities connected by relationships
  - **hierarchical model**
    - tree-like structure
    - group by records and links
    - navigational and procedural operations
  - **network model**
    - network structure
    - grouped by records and links
    - navigational and procedural operations
  - **relational model**
    - tables
    - tuples in relations
    - declarative operations
- **Constructs**
  - a data model concept which defines the structure of the DB
  - elements and their types
  - groups of elements
  - relationships between such groups
- **Operations**
  - basic model operations
    - `insert`
    - `delete`
    - `update`
    - `query`
  - user-defined operations
    - `compute_gpa`
    - `update_inventory`
- **Constraints**
  - specify restrictions on the data
  - implicit
    - defined by data model chosen
    - **entity integrity** constraint
      - primary key value cannot be null
    - **referential integrity** constraint

        - foreign key value must exist in the primary key of the referenced relation
      - **key** constraint
        - key values must be unique
      - **domain** constraint
        - values must exist in the domain of an attribute
  - explicit
    - expressed in the schema
    - using facilities provided by the model
  - semantic
    - defined in application programs
- **Physical data model**
  - low level
  - describe how data is stored physically
- **Conceptual data model**
  - high level
  - how the user will perceive data
  - how the user will access/modify data
- **Implementation data model**
  - somewhere between physical and conceptual
  - the sum of those two parts
- **Self-describing data model**
  - description of the data is combined with its values
- **Database schema**
  - description of data at some abstraction level
  - just the relations and attribute names
  - also called **intension**
- **Database instance**
  - a snapshot of the data at a given point in time
  - relations, attribute names, tuples
  - also called **extension**

1.4 Database Languages

- **DDL** (data definition language)
  - add or remove data
- **DML** (data manipulation language)
  - change data
- **QL** (query language)
  - query data

1.5 Relational Database Definitions

- **Schema of a relation**
  - denoted by $R(A_1, A_2, ..., A_n)$
  - R is the **name**
  - $A_1, A_2, ..., A_n$ are the **attributes**
- **Tuple**
  - ordered set of values
  - written : $< V_1, V_2, ..., V_n >$
    - each value V_n is derived from an appropriate domain
  - an *n-tuple* is a tuple with n values
- **Domain**

- three parts:
    - name
    - data type
    - set of **atomic** values (indivisible values)
- **Attribute**
  - attribute name designates a role played by a domain in a relation
  - can be the same as a domain name
    - e.g., a user-defined type `Name` which is the domain of an attribute also called `Name`
- **Cartesian product**
  - let $D_1, D_2, ..., D_n$ be a set of n domains
  - cartesian product on $D_1, D_2, ..., D_n$ is
    - $\{< d_1, d_2 >| d_1$ in D_1, d_2 in $D_2\}$
- **Relation**
  - a relation R of degree n on a collection of domains $D_1, D_2, ..., D_n$ consists of the following:
    - a schema $R(A_1, A_2, ..., A_n) \mid domain(A_i) = D_i$ with a one-to-one mapping
    - an instance r or R denoted by $r(R) \mid r(R) \subset D_1 \times D_2 \times ...D_n$
- **Superkey**
  - set of attributes such that no tuple has the same set of values for those attributes
- **Key**
  - a minimal superkey
  - i.e., no excess attributes
- **Primary key**
  - chosen, typically from the smallest key

2 Intro

2.1 Types of Database

- We are only concerned with **traditional applications**
- Business Data Processing (Numeric and Textual)

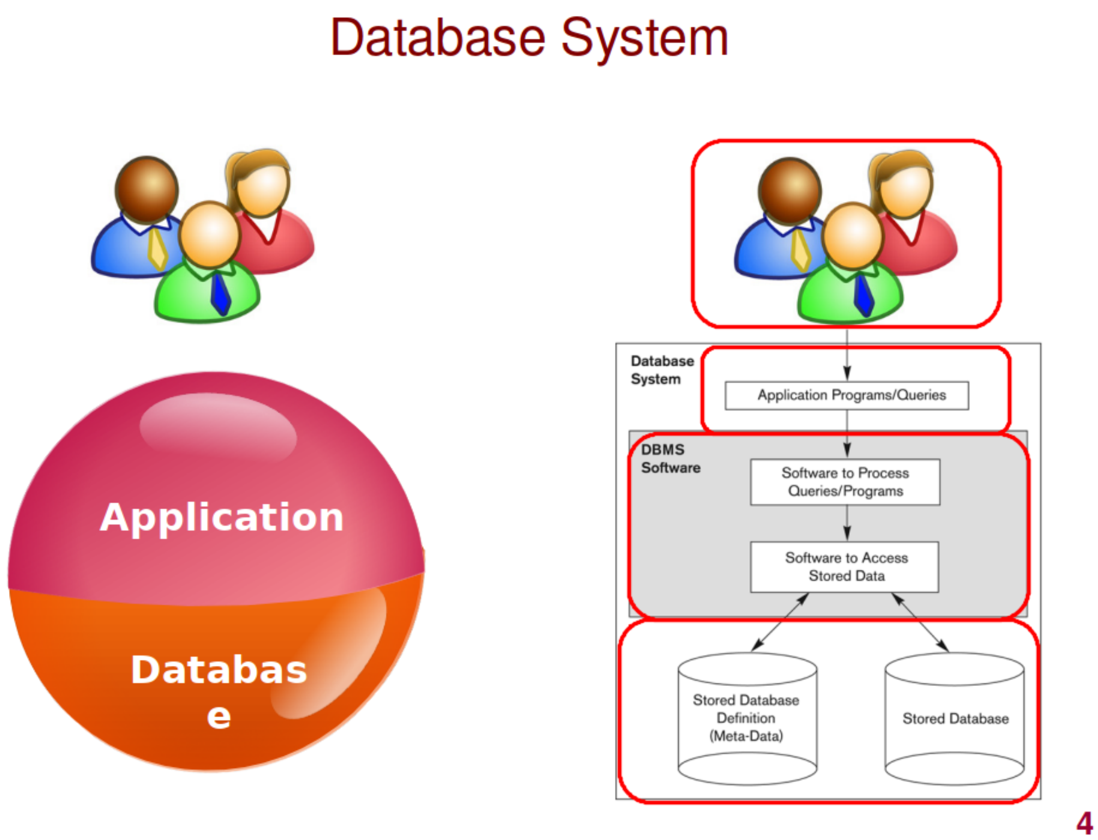


Figure 1: Database system diagram from Mengchi's slides.

2.2 DBMS Functionality

- **Load** initial database contents on a secondary storage medium
- **Define** a database in terms of:
  - data types
  - data structures
  - constraints
- **Manipulate** the database
  - retrieve
    - query
    - generate reports
  - modify
    - insert
    - delete
    - update
  - access
    - through web applications which provide a graphical front end
- **Handle concurrency** from multiple users
- **Security measures** to restrict unauthorized access
- **Presentation and visualization** of data
- **Maintenance** of database and application programs

2.3 Application/Database Interaction

- **Queries**
  - access data according to specifications and return a result
- **Transactions**
  - read data and update
  - store new data
- **No unauthorized access**
- Keep up with changing user requirements

2.4 Characteristics of the Database Approach

- **Self-Describing**
  - **catalog** stores descriptions of a database
    * data structures
    * data types
    * constraints
  - the description is called **meta-data**
  - allows the DBMS to work with many different applications
- **Insulation**
  - we can change the way the data is structured and organized without changing the application programs
- **Abstraction**
  - a **data model** is used to hide details
    * presents users with a *conceptual view* of the database
    * programmers refer to model constructs and not the nitty-gritty details
- **Multiple views**
  - each user can see a different view
  - **only see the data they care about**
- **Sharing data and multi-user transactions**
  - allow **concurrent** retrieval and modification of database
  - *concurrency control* guarantees either:
    * correct execution of a transaction OR
    * abortion of a transaction
  - *recovery* subsystem ensures each transaction's effect is correctly recorded
  - **OLTP** (online transaction processing) allows hundreds of concurrent transactions per second

2.5 Types of Database User

2.5.1 Actors Behind the Scenes

Those who design and develop DBMS software. Those who operate the computer systems.

- System designers and implementers
  - design and implement DBMS modules
- Tool developers
  - design and implement tools
    * modeling
    * designing
    * performance monitoring
    * prototyping
    * test data generation
    * UI creation

    * simulation
- Operators and maintenance personnel
  - tunnel rats
  - manage the running and maintenance of the DB

2.5.2 Actors on the Scene

Those who actually use and control the database content. Those who design, develop, and maintain database applications.

- DB administrators
  - acquire software and hardware resources
  - control the use of those resources
  - monitor efficiency
  - monitor use of DB
  - authorize access to DB
- DB designers
  - define the following aspects of a DB:
    * structure
    * constraints
    * content
    * transactions
  - must understand end users' needs
- System analysts
  - design applications and canned transactions for a DB
- Application developers
  - implement the specifications developed by analysts
- End users
  - use DB day-to-day
  - don't know or care how DB is structured
  - two categories:
    * naïve users
    * business analysts

3 Database System Concepts and Architecture

3.1 Data Representation

- We need to *abstract* the representation to make it meaningful

3.1.1 Hierarchical Model

- Tree-like structure
  - records
  - links
- Navigational and procedural operations

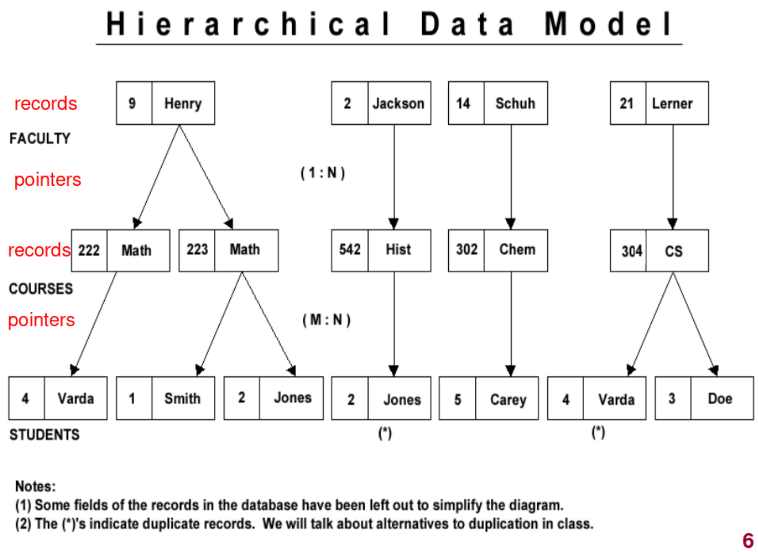


Figure 2: The hierarchical data model from Mengchi's slides.

3.1.2 Network Model

- Network structure
  - records
  - links
- Navigational and procedural operations

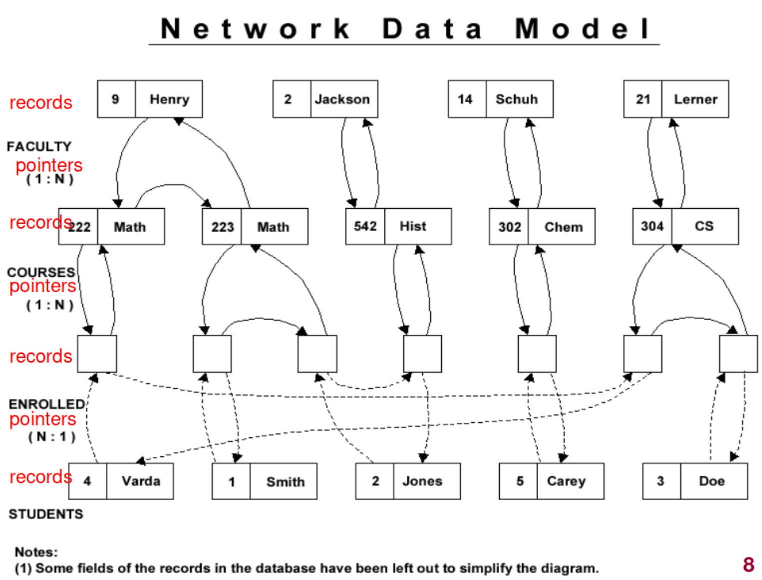
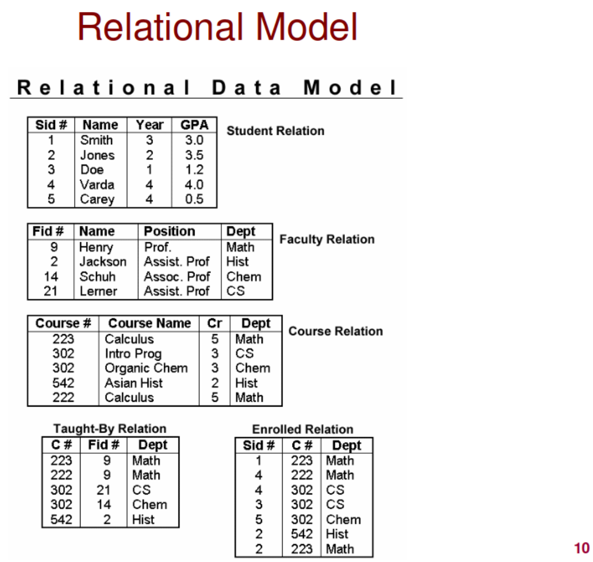


Figure 3: The network data model from Mengchi's slides.

3.1.3 Relational Model

- Tuples and relations

- Declarative operations specify what to get instead of how to get it



Relational Model

Relational Data Model

Student Relation

Sid #	Name	Year	GPA
1	Smith	3	3.0
2	Jones	2	3.5
3	Doe	1	1.2
4	Varda	4	4.0
5	Carey	4	0.5

Faculty Relation

Fid #	Name	Position	Dept
9	Henry	Prof.	Math
2	Jackson	Assist. Prof	Hist
14	Schuh	Assoc. Prof	Chem
21	Lerner	Assist. Prof	CS

Course Relation

Course #	Course Name	Cr	Dept
223	Calculus	5	Math
302	Intro Prog	3	CS
302	Organic Chem	3	Chem
542	Asian Hist	2	Hist
222	Calculus	5	Math

Taught-By Relation

C #	Fid #	Dept
223	9	Math
222	9	Math
302	21	CS
302	14	Chem
542	2	Hist

Enrolled Relation

Sid #	C #	Dept
1	223	Math
4	222	Math
4	302	CS
3	302	CS
5	302	Chem
2	542	Hist
2	223	Math

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Figure 4: The relational data model from Mengchi's slides.

3.2 Schemas

- Description of the data at some abstraction level
- Three levels, each with its own schema:
  - internal (physical)
    - how the data is stored, physically
    - physical storage structures
    - access paths
  - conceptual
    - structure and constraints for the whole database
    - high-level or implementation data model
  - external
    - user views
    - typically same data model as conceptual schema
- Physical data independence
  - change internal schema without changing the conceptual schema
- Logical data independence
  - change conceptual schema without changing external schema
- See Figure 5 for a trick here (ICE PL)

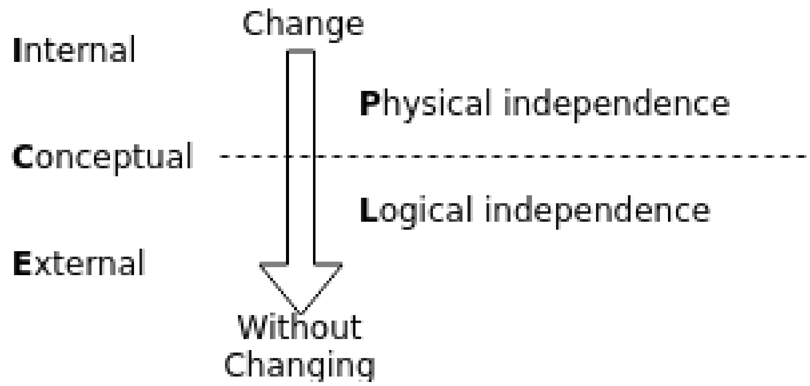

Figure 5: **ICE PL**, my trick for remembering schema types and which independence is which.

- Two important physical models
  - centralized
    - can still remote in but all processing is done centrally
  - client/server

3.3 Database Languages

- DDL (data definition language)
  - `insert`
  - `delete`
- DML (data manipulation language)
  - `update`
- QL (query language)
  - `get`
- SQL
  - combines all three

4 Relational Databases

4.1 Concepts

- Relation name
- Attributes (schema)
  - column headers
- Tuples (instance)
  - rows of entries in the table
- Domain
  - the set of all possible values of an attribute

4.2 Summary of Definitions

Informal Terms	Formal Terms
Table	Relation
Column Name	Attribute

Informal Terms	Formal Terms
All Possible Column Values	Domain
Row	Tuple
Table Definition	Schema of a Relation
Populated Table	Instance of a Relation

4.3 Characteristics of a Relation

- No duplicate tuples
  - that is an instance of a relation is a **set of tuples**
- This set of tuples is unordered
  - a set has no order
- Attributes of a relation are unordered
  - the heading is a set
- All domains consist of atomic values only
  - `NULL` can be assigned to values which are unknown or inapplicable
  - providing there is no **`not null`** constraint

4.4 Accessing a Tuple's Members

- We define a *n-tuple* t as follows:
  - $t =< A_1 : v_1, ..., A_n : v_n >$
- Accessing a single element is trivial and can be done in two ways:
  - $t[A_i]$
  - $t.A_i$
- Accessing multiple elements can be done as follows:
  - $t[A_u, A_v, A_w] =< v_u, v_v, v_w >$

4.5 Constraints

- **Implicit** (inherent) constraints
  - based on the data model itself
  - relational model does not allow a list as a value
    - *values* must be *atomic*
- **Explicit** (schema-based) constraints
  - expressed in the schema
  - uniqueness
  - not null
  - primary key
  - etc.
- **Semantic** (application-based) constraints
  - beyond the scope of what can be defined in a data model
  - defined and enforced in application programs

In the relational model, we separate into three further categories of constraint:

- **Key** constraints
  - for any superkey of R, the following will hold, provided R is in a **valid state**:
    - no two tuples will have the same attributes for the superkey
    - that is, $t_i[superkey] \neq t_j[superkey]$
  - for any key of R, the following will hold, provided R is in a **valid state**:

        - the key is a superkey such that the removal of any of its attributes will violate the superkey constraint above
    - the primary key is chosen, typically from the smallest key
        - sometimes it makes more sense to choose something else
- **Entity integrity** constraints
    - the primary key attribute(s) of each relation schema R cannot have null values
- **Referential integrity** constraints
    - referencing relation, referenced relation
        - these *can* be the same relation
    - **referencing** relation has *foreign key* attributes which identify the **referenced relation**
    - the value(s) of a foreign key must be either an existing primary key value in the referenced relation or null
- And *implicitly* a fourth constraint, the **domain constraint**
    - that is, every value in a tuple must be from the domain of its attribute

4.6 Any Problems?

- Modification operations pose an issue
    - updates shouldn't violate integrity constraints
    - may be necessary to cascade updates to preserve integrity
    - the `INSERT` problem
        - insert may violate any of the three constraints outlined above or the domain constraint
        - domain
            - if one of the values for the inserted tuple is not in the attribute's domain
        - key
            - if the value(s) of the key attribute in the new tuple already exist(s) in another tuple in the relation
        - referential integrity
            - if a foreign key in the new tuple references a primary key value which does not exist in the referenced relation
        - entity integrity
            - primary key value is null in the new tuple
    - the `DELETE` problem
        - can cause a referential integrity problem in all referencing relations, if one or more exists
        - solutions include
            - reject the deletion
            - cascade the deletion
            - set the foreign keys in referencing relations to null
    - the `UPDATE` problem
        - an `UPDATE` can be regarded as an `INSERT` followed immediately by a `DELETE`
        - depending on the attribute being updated, a number of issues can occur
            - **foreign key** $\implies$ possible referential integrity violation or domain violation
            - **primary key** $\implies$ possible key constraint, referential integrity, entity integrity, or domain violation
            - **ordinary attribute** $\implies$ only domain constraint can be violated

5 ALG

- **Relational algebra**

6 TRC

- **Tuple relational calculus**

7 DRC and QBE

7.1 DRC

- **Domain relational calculus**

7.2 QBE

- **Query by example**
- User-friendly version of DRC

8 SQL

- Structured query language
- Combines three languages
  - DDL
    - schema creation and modification
    - access control
    - `CREATE`, `ALTER`, `DROP`
  - DML
    - data insert, update, delete
    - `INSERT`, `DELETE`, `UPDATE`
  - QL
    - data query
    - `SELECT`
- The most common DB language
- Implemented in all commercial DBs
- Some SQL commands:
  - `CREATE TABLE` (or `VIEW`)
  - `ALTER  TABLE`
  - `DROP   TABLE`
- Two kinds of relations:
  - **base relations**
    - actually created
    - stored as a file
  - **virtual relations**
    - defined as a query
    - not actually stored

8.1 Temporary Tables

Create a temporary table to be **deleted on commit**.

```sql
CREATE GLOBAL TEMPORARY TABLE TempTable (
id NUMBER,
description VARCHAR2(20)
) ON COMMIT DELETE ROWS;
```

Create a temporary table to be **deleted at the end of the session**.

```sql
CREATE GLOBAL TEMPORARY TABLE TempTable (
id NUMBER,
description VARCHAR2(20)
) ON COMMIT PRESERVE ROWS;
```

8.2 Organization

- `HEAP`
  - default value
  - data is stored in no particular order in the table
- `INDEX`
  - index-organized table
  - data rows are held in an index
    - this index will be the primary key for the table
- `EXTERNAL`
  - read-only table located outside the database

8.3 Data Types and Domains

- **Numerics**
  - `INTEGER`, `INT`, `SMALLINT`
  - `FLOAT`, `REAL`, `DOUBLE PRECISION`
- **Char/String Literals**
  - `CHAR(n)`, `CHARACTER(n)`
  - `VARCHAR(n)`, `CHAR VARYING(n)`, `CHARACTER VARYING(n)`, `VARCHAR2(n)`
- **Bitstrings**
  - `BIT(n)`
    - **Booleans**
      - `1`, `0`, `NULL`
  - `BIT VARYING(n)`
- **Dates**
  - format is `YYYY-MM-DD`
- Other data types
  - `TIMESTAMP`
    - date and time
    - optional `WITH TIME ZONE` qualifier
  - `INTERVAL`
    - relative value that can be used to increment or decrement an absolute value
      - date
      - time
      - timestamp
  - these can all be cast to string format for comparison
- We can also **create domains** to define our own data types as follows:
  - `CREATE DOMAIN YOUR_TYPE_HERE as EXISTING_TYPE_HERE`
  - This helps improve schema readability.

- It is also possible, in *object oriented applications only* to have truly user defined types
  - CREATE TYPE

8.4 Creating Some Relations

8.4.1 Inline Constraints

```
CREATE TABLE EXAMPLE(
E# CHAR(4) PRIMARY KEY,
B# CHAR(4) NOT NULL UNIQUE
);
```

8.4.2 Offline Constraints

```
CREATE TABLE EXAMPLE(
E# CHAR(4),
B# CHAR(4),
PRIMARY KEY(E#),
NOT NULL(B#),
UNIQUE(B#)
);
```

Sometimes it is necessary to have it this way, for example if we want a combination primary key:

```
CREATE TABLE EXAMPLE(
E# CHAR(4),
B# CHAR(4),
PRIMARY KEY(E#,B#)
);
```

8.4.3 Some Constraints

- `DEFAULT <value_here>`
- `NOT NULL`
- `CHECK (ATTRIBUTE_NAME >` v_1 `AND ATTRIBUTE_NAME <` v_2`)`
  - any boolean expression can go inside the parentheses
- `PRIMARY KEY`
- `UNIQUE`
- referential integrity options
  - `RESTRICT`
  - `CASCADE`
  - `SET NULL`
  - `SET DEFAULT`

8.5 Dropping and Modifying Relations

- Delete a table
  - `DROP TABLE <table>`
- Insert a tuple into the table
  - `INSERT into <table> values(`$v_1, v_2, ..., v_n$`)`

- Delete a tuple in a table
  - `DELETE from <table> WHERE <condition>`
- Modify attribute values of one or more tuples
  - `UPDATE <table> SET <attribute> = <value> WHERE <condition>`
  - omitting the `WHERE` clause specifies that all tuples in a relation be updated

9 ER/EER Mapping

9.1 ER and EER

9.1.1 Regular (Strong) Entities

- create a relation R with all **simple attributes** of E
- choose a **primary key**
  - composite primary key $\implies$ composite set of **simple attributes** will form the primary key.

9.1.2 Weak Entities

- **do not map** the relationship between E and W
- create a relation R with **all attributes** of W
- add **primary key** of E as a **foreign key** of R
- the **primary key** of R is a combination of **primary key(s)** of E and the **partial key** of W if any

9.1.3 Binary 1:1 Relations

- let R be a relationship; S be an entity; T be an entity with total participation
- **if** S **does not also have** total participation:
  - add a **foreign key** to T which points to **primary key** of S
- **if** S **also has** total participation
  - **merge** S and T into a **single relation**

9.1.4 Binary 1:N Relations

- let T be **total participation** entity (**arity N**); let S be the other entity (**arity 1**)
- T is greedy
  - add a **foreign key** to T which points to **primary key** in S
  - all **simple attributes** of their relationship go to T

9.1.5 Binary M:N Relations

- let S and T be two the two entities in the relationship
- create a new relation R for the relationship
  - *relationship relation*
- include **primary keys** of S and T as **foreign keys** in R
  - these foreign keys **in combination** will form the **primary key**
- include any **simple attributes** of the relationship as attributes of R

9.1.6 Convert Multivalue Attributes to Entities

- let A be a **multivalued attribute** and S be an entity
- create a new relation R
  - **foreign key** points to primary key in S
  - give R combination of A and the **foreign key** as a **primary key**

9.1.7 N-ary Relations

- let S_n be the **entities in N-ary relationship** of arity n
- create a new relation R
  - R will have as a **primary key** a set of **foreign keys** pointing to $S_1, S_2, \ldots, S_n$
  - include **simple attributes** of the relationship as attributes of R

9.2 Further Steps for EER

9.2.1 Options for Mapping Spec/Gen

- **Four options:**
  1. **Multiple relations for superclass and subclass**
     - each *subclass* has a **foreign key** which is also **its primary key**; points to the *superclass*
     - additionally, all simple attributes of the *subclass*
     - simple attributes of *superclass* are left up there
  2. **Multiple relations for subclass only**
     - *WARNING:* this option only works for total subclasses (i.e. **every entity in the superclass must belong to one and only one of the subclasses**)
     - this constraint makes sense because otherwise you would have duplicate values
     - simply create a tuple for each *subclass* which inherits attributes from the *superclass*
  3. **Single relation with one discriminating attribute**
     - **discriminating attribute** indicates which subclass the entity belongs to
     - has all attributes of *superclasses* and *subclasses* (obviously some will be null)
  4. **Single superclass relation with indicators**
     - shared attributes at the front
     - followed by indicator for each *subclass* with its own attributes
- **Multiple inheritance mapping...**
  - they must all have the same **key** attribute(s)
  - we can still apply any of the above techniques subject to the few retrictions

9.2.2 Mapping Union Sets (Categories)

- *owner* class is a *subclass* of multiple *superclasses*
- *superclasses* have **different keys**
- each get a new attribute called a **surrogate key** which is a **foreign key** pointing to *owner's* **primary key**

10 Embedded SQL and PLSQL