Database Systems

L12: Revisions

Motivation ❶❷ | Syntax | PL/pgSQL

Parameterized Query

Username = " ' ; DROP TABLE Users;
SELECT " "

Issue #1

SQL query contains **no variable**.

```
SELECT password
FROM   Users
WHERE  username = 'Alice';
```

Issue #2

Dynamic creation of SQL query is vulnerable to **SQL injection attack**.

```
query = "SELECT password "
      + "FROM   Users "
      + "WHERE  username = '" + username + "';";
```

Cursors

Issue

Some problems are easier to solve in **imperative** way.

- *i.e.*, describe how rather than what.
- *e.g.*, finding the difference in mark between current student and next highest student (*in some order*) which may include duplicate values.

Functions/procedures with control flow is Turing complete.

- Anything that can be computed can be computed using functions/procedures.

Function

Declaration

```
CREATE OR REPLACE FUNCTION <name>
  (<param_name> <param_type>,
   <param_name> <param_type>, ...)
RETURNS <return_type> AS $$

  <code>

$$ LANGUAGE <language>;
```

Note

- Returns a value.
- Invoke using SELECT.

Procedure

Declaration

```
CREATE OR REPLACE PROCEDURE <name>
  (<param_name> <param_type>,
   <param_name> <param_type>, ...)
RETURNS <return_type> AS $$

  <code>

$$ LANGUAGE <language>;
```

Note

- Does not return any value.
- Invoke using CALL.

Variables

Declaration

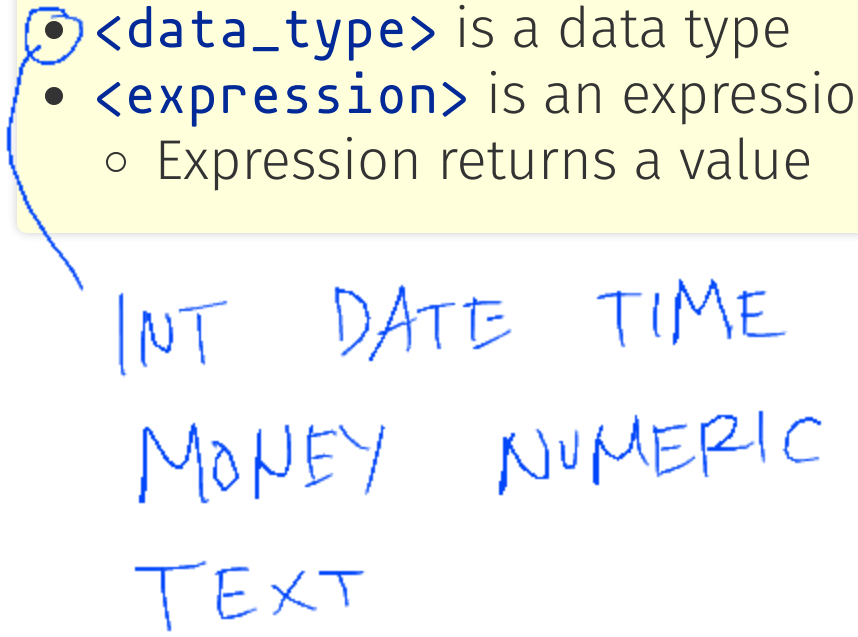
```
DECLARE
  [<var_name> <data_type>;]
  [<var_name> <data_type>;]
  [<var_name> <data_type>;]
    :
```

Assignment

```
<var_name> := <expression>
```

Note

- `<var_name>` is a variable name
- `<data_type>` is a data type
- `<expression>` is an expression
  - Expression returns a value



Selection

IF-THEN-ELSE

```
IF <condition> THEN
  <statement>
[ELSIF <condition> THEN
  <statement>]
[ELSIF <condition> THEN
  <statement>]
    :
[ELSE
  <statement>]
END IF
```

Note

- You can have 0 or more `ELSIF`
  - Can also be spelled `ELSEIF`
- You can have 0 or 1 `ELSE`
  - Must be after all the `ELSIF`
- `<condition>` is a conditional expression
  - Returns a boolean value
  - Condition is satisfied if it evaluates to `TRUE`
- `<statement>` is a statement
  - Code evaluated for its effect and not return value

Repetition

Loop

```
LOOP
  EXIT <label> WHEN <condition>;
  <statement>
END LOOP;
```

Note

This is an infinite loop with a break condition.

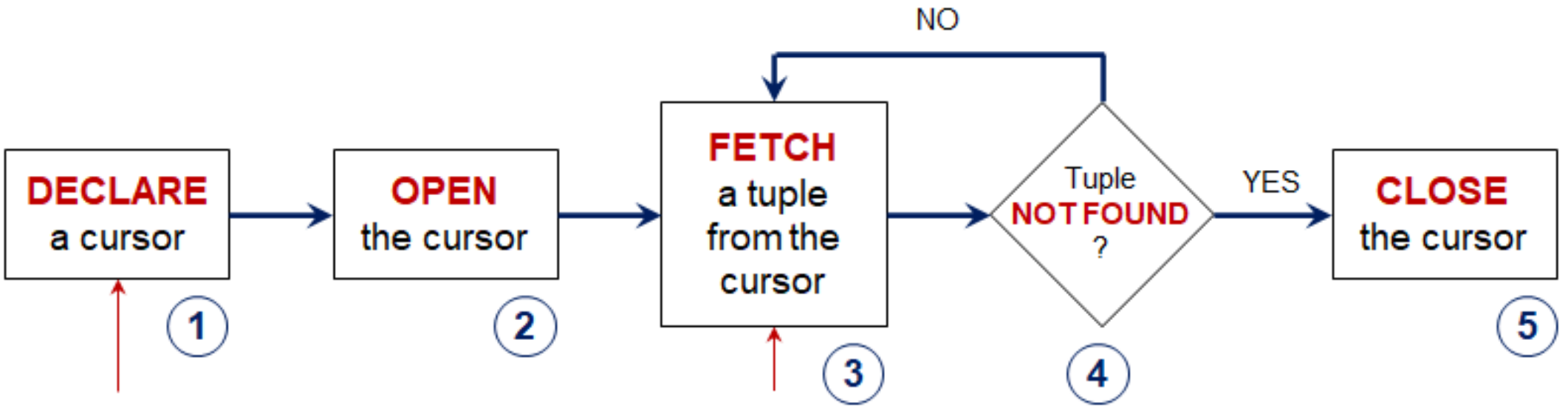
While-Loop

```
WHILE <condition>
LOOP
  <statement>
END LOOP;
```

For-Loop

```
FOR <var_name> IN <lower> .. <upper>
LOOP
  <statement>
END LOOP;
```

Cursor



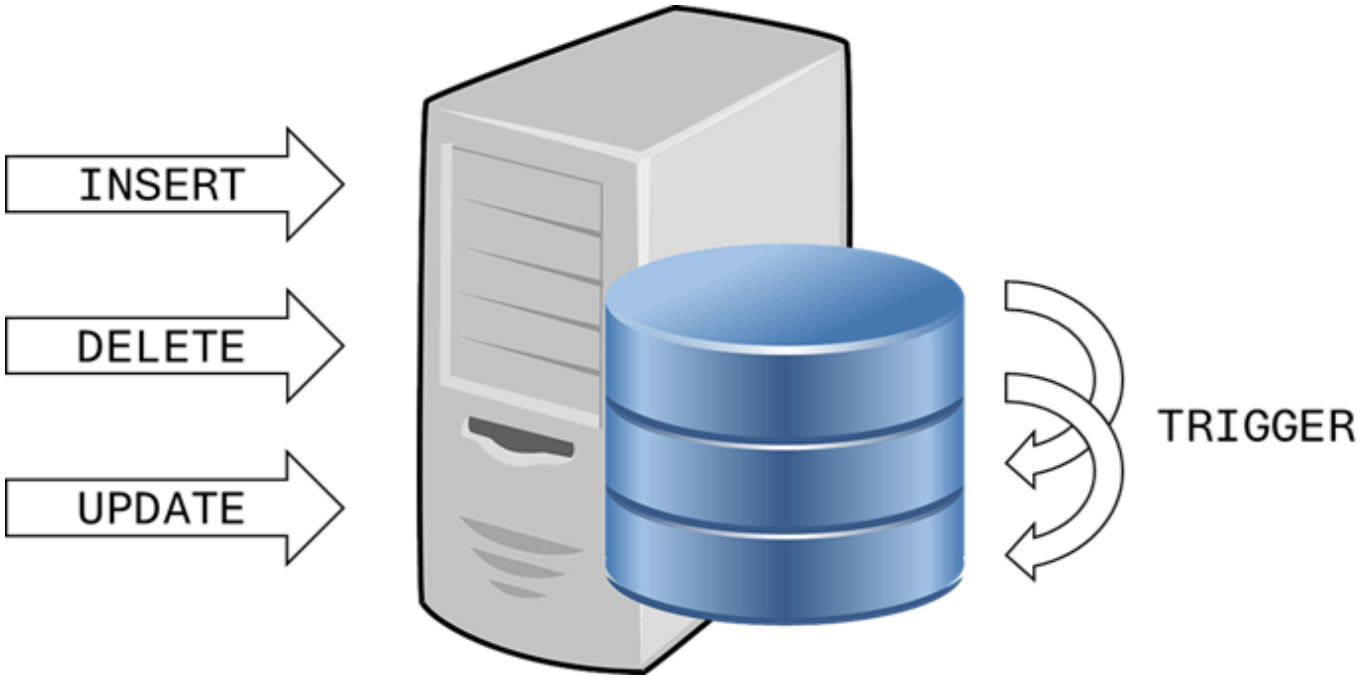
LOOP → FETCH
EXIT WHEN NOT FOUND

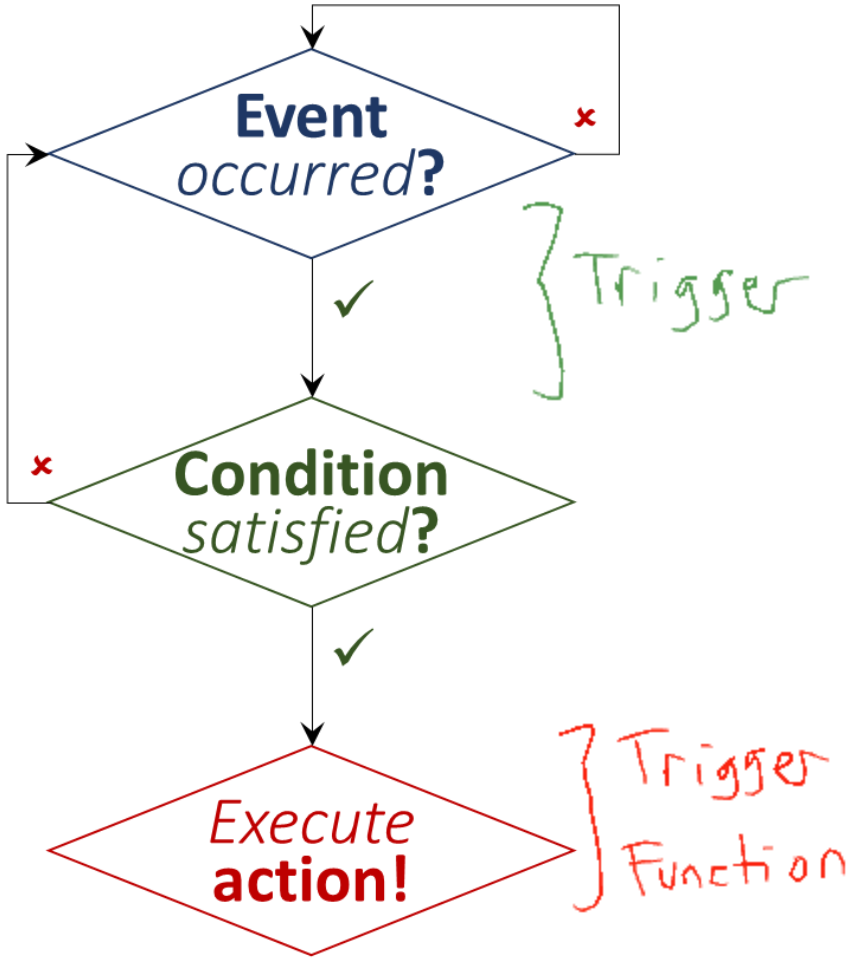
END LOOP;

Event-Condition-Action

Event-Condition-Action

A **trigger** is a procedure or function executed when a database **event** occurs on a table.





Trigger Function

Syntax

```
CREATE OR REPLACE FUNCTION <func>()
RETURNS TRIGGER AS $$
BEGIN
  <code>
END;
$$ LANGUAGE plpgsql;
```

Trigger

Syntax

```
CREATE TRIGGER <name>
<trigger_timing> <trigger_event>
  ON <table>
FOR EACH <trigger_granularity>
  [WHEN <condition>]
  EXECUTE FUNCTION <func>();
```

Same name

Timings

Keywords

BEFORE, AFTER, INSTEAD OF *(only for `VIEW`)*

- `BEFORE` trigger is executed **before the event**.
  - May modify/cancel the event by using ***return value***.
- `AFTER` trigger is executed **after the event**
  - The event already occurred, cancellation done using `EXCEPTION`.

Example

```
CREATE TRIGGER log_all
AFTER
  INSERT OR DELETE OR UPDATE ON Table
FOR EACH ROW
WHEN (condition)
EXECUTE FUNCTION log_function();
```

Events

Keywords

INSERT, DELETE, UPDATE

- May check for multiple events using `OR` keyword.
- The triggering operation is captured in the special variable called `TG_OP` *(in uppercase)*.

Example

```
CREATE TRIGGER log_all
AFTER
  INSERT OR DELETE OR UPDATE ON Table
FOR EACH ROW
WHEN (condition)
EXECUTE FUNCTION log_function();
```

Granularity

Keywords

row-level statement-level

FOR EACH ROW, FOR EACH STATEMENT

- Some *checks* may only need to be done once regardless of how many rows are affected.
  - *e.g.*, checking all groups have more than one person.
- Return value has no effect on the subsequent operations.
  - Cancellation has to be done using `EXCEPTION` for statement-level.

Example

```
CREATE TRIGGER log_all
AFTER
  INSERT OR DELETE OR UPDATE ON Table
FOR EACH ROW
WHEN (condition)
EXECUTE FUNCTION log_function();
```

Condition

Keywords

WHEN

- NO SELECT in WHEN()
- NO OLD in WHEN() for INSERT
- NO NEW in WHEN() for DELETE
- NO WHEN() for INSTEAD OF

Example

```
CREATE TRIGGER log_all
AFTER
  INSERT OR DELETE OR UPDATE ON Table
FOR EACH ROW
WHEN (condition)
EXECUTE FUNCTION log_function();
```

Variables

Transition Variables

- Every row-granularity operation on database can be abstracted into a modification of a row
  - `INSERT`: → new value `(NEW)`
  - `UPDATE`: old value `(OLD)` → new value `(NEW)`
  - `DELETE`: old value `(OLD)` →
- `OLD` and `NEW` *signals* our "***intention***"
  - `NEW` is known even *before* the EVENT is executed
  - `OLD` is known even *after* the EVENT finished executing
- The *intention* can be *modified* before the EVENT is executed
  - This is where the return value is important
  - Whatever we return is the new intention

Non-NULL Value

Events	OLD	NEW
INSERT	✗	✓
UPDATE	✓	✓
DELETE	✓	✗

Not all values are available for all operations. If the value is not available, the value is `NULL`.

- `OLD` is `NULL` value on `INSERT`.
- `NEW` is `NULL` value on `DELETE`.

Return Values

Non-NULL Value

Events + Timings	NULL Tuple	Non-NULL Tuple `t`

`BEFORE INSERT`
`BEFORE UPDATE`
`BEFORE DELETE`
	No insertion
	No update
	No deletion
		Tuple **`t`** will be inserted
		Tuple **`t`** will be the *updated* tuple
		Deletion proceeds as normal (**`t`** is ignored)

`AFTER INSERT`
`AFTER UPDATE`
`AFTER DELETE`
	NO EFFECT	**NO EFFECT**

Deferrable Trigger

Keywords

CONSTRAINT, DEFERRABLE, INITIALLY DEFERRED, INITIALLY IMMEDIATE

- Checked only at the **end of the transaction**.
- Require the `CONSTRAINT` keyword.
- Can only be `AFTER` trigger.
- Can only be `FOR EACH ROW` trigger.

```
CREATE CONSTRAINT TRIGGER <trigger_name>
<trigger_timing> <trigger_event> ON <trigger_table>
[ DEFERRABLE INITIALLY [ DEFERRED | IMMEDIATE ] ]
FOR EACH <trigger_granularity>
  [ WHEN <trigger_condition> ]
EXECUTE FUNCTION <trigger_function_name>();
```

Deferrable Trigger

Activation Order

For the **same event** on the **same table**:

1. `BEFORE` statement-level triggers
2. `BEFORE` row-level triggers
3. **EVENT** for the given **ROW**
4. `AFTER` row-level triggers
5. `AFTER` statement-level triggers

Within the **same category**: alphabetical order.

Note

IF (2) returns `NULL`, then (3) and (4) are cancelled.

Break

Back by 12:39

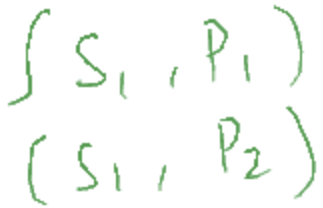
Quiz #1

Question

Consider the attribute mapping on the right. Given the following requirement, which functional dependency captures this requirement?

Each shop can sell at most one product

Attribute	Letter
User	U
Product	P
Shop	S
Cost	C
Date	D



	Choice	Comment	
A	{P,D} → {S}	NO	✗
B	{P} → {U}	NO	✗
C	{U,P,S,D} → {C}	NO	✗
D	{S} → {P}	YES	✓
E	{P} → {S}	NO	✗

Quiz #2

Question

Consider the attribute mapping on the right. Given the following requirement, which functional dependency captures this requirement?

No two different users can buy the same product

Attribute	Letter
User	U
Product	P
Shop	S
Cost	C
Date	D

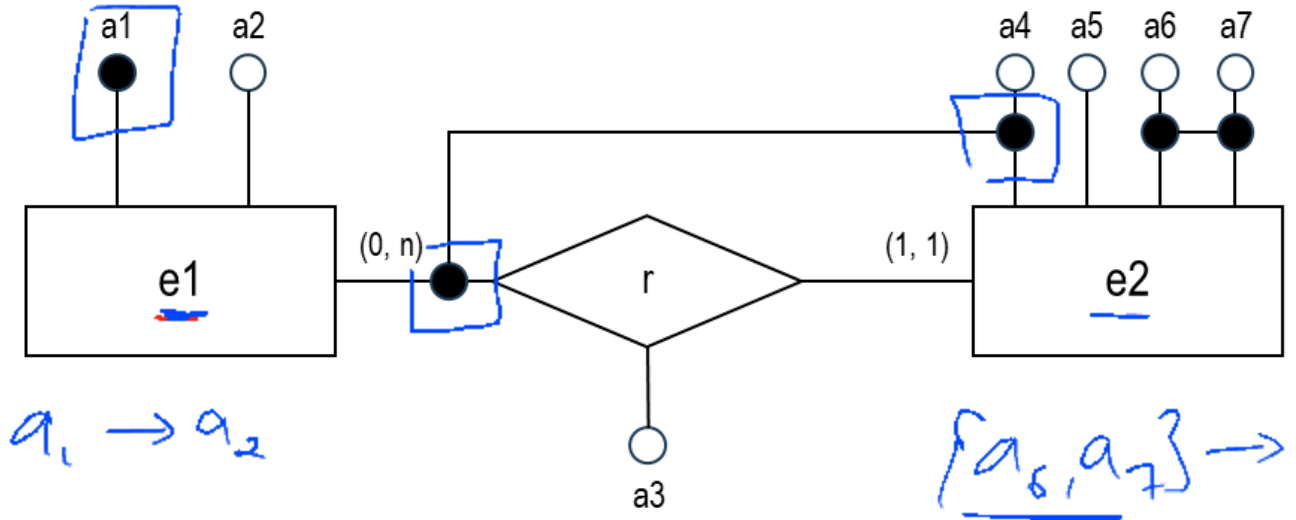
	Choice	Comment	
A	{P,D} → {S}	*NO*	✗
B	{P} → {U}	*YES*	✓
C	{U,P,S,D} → {C}	*NO*	✗
D	{S} → {P}	*NO*	✗
E	{P} → {S}	*NO*	✗

$e_2(a_1, a_4, a_5, a_6, a_7)$

Quiz #3

Question

Consider the entity-relationship diagram on the right. Which functional dependency holds?



$a_1 \rightarrow a_2$

$\{a_6, a_7\} \rightarrow e_2$

$\{a_1, a_4\} \rightarrow e_2$

	Choice	Comment	
A	{a1} → {a4}	*NO: this is key of **e1***	✗
B	{a4} → {a1}	*NO: this is partial key*	✗
C	{a4} → {a5,a6,a7}	*NO: this is partial key*	✗
D	{a6,a7} → {a1}	*YES: this is not partial key*	✓
E	None of the above	*NO*	✗

Functional Dependencies ❶❷❸❹ | Normalization | Understanding

Quiz #4

Question

Consider the functional dependency below. Which table on the right is a valid table with respect to the functional dependency below?

$$\{A, C\} \rightarrow \{B\}$$

T1

A	B	C
1	1	1
1	2	1
2	2	1

T2

A	B	C
1	1	1
1	1	1
2	2	2

T3

A	B	C
2	2	2
1	1	1
1	2	1

T4

A	B	C
1	1	1
2	1	2
1	2	1

	Choice	Comment	
A	T1	*NO: see row 1 and 2*	✗
B	T2	*YES: not proper because of duplicate but valid*	✓
C	T3	*NO: see tow 2 and 3*	✗
D	T4	*NO: see tow 1 and 3*	✗

Example

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Reduce complexity in checking

- Superkeys
- Candidate keys
- Prime attributes
- BCNF violation
- 3NF violation

2. Compute Minimal Cover

Reduce complexity in computing

- Attribute closure
- Projection
- Lossless-join
- Dependency preserving
- 3NF synthesis

{ {B}, {A,D}, {A,C} }

Computation #1

$R = \{A, B, C, D, E\}$

$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

$A^+ = A$

$B^+ = ABCDE = R$

C^+

D^+

E^+

AC^+

AD^+

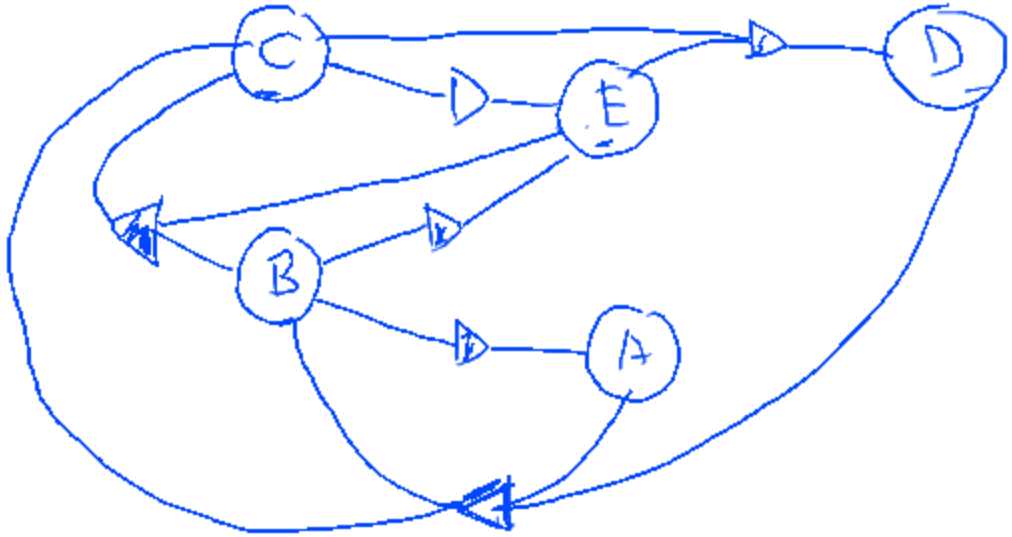
AE^+

CD^+

CE^+

DE^+

2. Compute Minimal Cover



Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Singleton

$\{A\}^+$
$\{B\}^+$
$\{C\}^+$
$\{D\}^+$
$\{E\}^+$

2. Compute Minimal Cover

Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Singleton

$\{A\}^+ = \{A\}$
$\{B\}^+ = \{A,B,C,D,E\}$
$\{C\}^+ = \{C,D,E\}$
$\{D\}^+ = \{D\}$
$\{E\}^+ = \{E\}$

2. Compute Minimal Cover

Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Singleton

$\{A\}^+ = \{A\}$
$\{B\}^+ = \{A,B,C,D,E\}$ ✓
$\{C\}^+ = \{C,D,E\}$
$\{D\}^+ = \{D\}$
$\{E\}^+ = \{E\}$

2. Compute Minimal Cover

Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Pair $\{B\}$

2. Compute Minimal Cover

Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Pair $\{B\}$

$\{A,C\}^+$
$\{A,D\}^+$
$\{A,E\}^+$
$\{C,D\}^+$
$\{C,E\}^+$
$\{D,E\}^+$

2. Compute Minimal Cover

Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Pair $\{B\}$

$\{A,C\}^+ = \{A,B,C,D,E\}$
$\{A,D\}^+ = \{A,B,C,D,E\}$
$\{A,E\}^+ = \{A,E\}$
$\{C,D\}^+ = \{C,D,E\}$
$\{C,E\}^+ = \{C,D,E\}$
$\{D,E\}^+ = \{D,E\}$

2. Compute Minimal Cover

Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Pair $\{B\}$

$\{A,C\}^+ = \{A,B,C,D,E\}$ ✓
$\{A,D\}^+ = \{A,B,C,D,E\}$ ✓
$\{A,E\}^+ = \{A,E\}$
$\{C,D\}^+ = \{C,D,E\}$
$\{C,E\}^+ = \{C,D,E\}$
$\{D,E\}^+ = \{D,E\}$

2. Compute Minimal Cover

Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Triple {A,D} {A,C} {B}

2. Compute Minimal Cover

Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Triple {A,D} {A,C} {B}

$\{C,D,E\}^+ = \{C,D,E\}$

2. Compute Minimal Cover

Computation #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {E}
{B} → {A}
{C,E} → {D}
{B,E} → {C}
{A,D} → {B}
{A,D} → {C}

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {E}
{B} → {A}
{C,E} → {D}
{B,E} → {C}
{A,D} → {B}
{A,D} → {C}

Consider {C,E} → {D}

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {E}
{B} → {A}
{C,E} → {D}
{B,E} → {C}
{A,D} → {B}
{A,D} → {C}

Consider {C,E} → {D}
Can we remove C?

Computation #2

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: $\{A,D\}$ $\{A,C\}$ $\{B\}$

2. Compute Minimal Cover

$\{C\} \rightarrow \{E\}$ **$\{C,E\} \rightarrow \{D\}$** $\{A,D\} \rightarrow \{B\}$
$\{B\} \rightarrow \{E\}$ $\{B,E\} \rightarrow \{C\}$ $\{A,D\} \rightarrow \{C\}$
$\{B\} \rightarrow \{A\}$

Consider $\{C,E\} \rightarrow \{D\}$
Can we remove C?
$\{E\}^+ = \{E\} \not\supseteq \{D\}$
$\Rightarrow$ cannot remove C

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {E}
{B} → {A}
{C,E} → {D}
{B,E} → {C}
{A,D} → {B}
{A,D} → {C}

Consider {C,E} → {D}
Can we remove E?

Computation #2

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: $\{A,D\}$ $\{A,C\}$ $\{B\}$

2. Compute Minimal Cover

$\{C\} \rightarrow \{E\}$ **$\{C,E\} \rightarrow \{D\}$** $\{A,D\} \rightarrow \{B\}$
$\{B\} \rightarrow \{E\}$ $\{B,E\} \rightarrow \{C\}$ $\{A,D\} \rightarrow \{C\}$
$\{B\} \rightarrow \{A\}$

Consider $\{C,E\} \rightarrow \{D\}$
Can we remove E?
$\{C\}^+ = \{C,D,E\} \supseteq \{D\}$
$\Rightarrow$ can remove E

Computation #2

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}	**{C} → {D}**	{A,D} → {B}
{B} → {E}	{B,E} → {C}	{A,D} → {C}
{B} → {A}		

Computation #2

$R = \{A, B, C, D, E\}$

$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

$\{C\} \rightarrow \{E\}$
$\{B\} \rightarrow \{E\}$
$\{B\} \rightarrow \{A\}$

$\{C\} \rightarrow \{D\}$
$\{B,E\} \rightarrow \{C\}$

$\{A,D\} \rightarrow \{B\}$
$\{A,D\} \rightarrow \{C\}$

Consider

$\{B,E\} \rightarrow \{C\}$ => $B \rightarrow C$

$\{A,D\} \rightarrow \{B\}$

$\{A,D\} \rightarrow \{C\}$

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {E}
{B} → {A}

{C} → {D}
{B,E} → {C}

{A,D} → {B}
{A,D} → {C}

Consider

{B,E} → {C}
{A,D} → {B}
{A,D} → {C}

{B} → {C}
{A,D} → {B}
{A,D} → {C}

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {E}
{B} → {A}
{C} → {D}
{B} → {C}
{A,D} → {B}
{A,D} → {C}

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {E}
{B} → {A}
{C} → {D}
{B} → {C}
{A,D} → {B}
{A,D} → {C}

Consider {C} → {E}, can we remove this?
First assume no {C} → {E}

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

~~{C} → {E}~~
{B} → {E}
{B} → {A}
{C} → {D}
{B} → {C}
{A,D} → {B}
{A,D} → {C}

Consider {C} → {E}, can we remove this?
First assume no {C} → {E}
$\{C\}^+ = \{C,D\} \not\supseteq \{E\}$

Computation #2

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: $\{A,D\}$ $\{A,C\}$ $\{B\}$

2. Compute Minimal Cover

~~$\{C\} \rightarrow \{E\}$~~ $\{C\} \rightarrow \{D\}$ $\{A,D\} \rightarrow \{B\}$
$\{B\} \rightarrow \{E\}$ $\{B\} \rightarrow \{C\}$ $\{A,D\} \rightarrow \{C\}$
$\{B\} \rightarrow \{A\}$

Consider $\{C\} \rightarrow \{E\}$, can we remove this?

First assume no $\{C\} \rightarrow \{E\}$

$\{C\}^+ = \{C,D\} \not\supseteq \{E\}$

$\Rightarrow$ cannot remove $\{C\} \rightarrow \{E\}$

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {E}
{B} → {A}

{C} → {D}
{B} → {C}

{A,D} → {B}
{A,D} → {C}

Consider {B} → {E}, can we remove this?
First assume no {B} → {E}

Computation #2

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: $\{A,D\}$ $\{A,C\}$ $\{B\}$

2. Compute Minimal Cover

$\{C\} \rightarrow \{E\}$
~~$\{B\} \rightarrow \{E\}$~~
$\{B\} \rightarrow \{A\}$

$\{C\} \rightarrow \{D\}$
$\{B\} \rightarrow \{C\}$

$\{A,D\} \rightarrow \{B\}$
$\{A,D\} \rightarrow \{C\}$

Consider $\{B\} \rightarrow \{E\}$, can we remove this?

First assume no $\{B\} \rightarrow \{E\}$

$\{B\}^+ = \{A,B,C,D,E\} \supseteq \{E\}$

Computation #2

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: $\{A,D\}$ $\{A,C\}$ $\{B\}$

2. Compute Minimal Cover

$\{C\} \rightarrow \{E\}$ $\quad$ $\{C\} \rightarrow \{D\}$ $\quad$ $\{A,D\} \rightarrow \{B\}$
$\{B\} \rightarrow \{E\}$ $\quad$ $\{B\} \rightarrow \{C\}$ $\quad$ $\{A,D\} \rightarrow \{C\}$
$\{B\} \rightarrow \{A\}$

Consider $\{B\} \rightarrow \{E\}$, can we remove this?

First assume no $\{B\} \rightarrow \{E\}$

$\{B\}^+ = \{A,B,C,D,E\} \supseteq \{E\}$

$\Rightarrow$ can remove $\{B\} \rightarrow \{E\}$

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{C} → {D}
{B} → {C}
{A,D} → {B}
{A,D} → {C}
{B} → {A}

Consider {B} → {A}, can we remove this?

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {A}
{C} → {D}
{B} → {C}
{A,D} → {B}
{A,D} → {C}

Consider {C} → {D}, can we remove this?

Computation #2

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: $\{A,D\}$ $\{A,C\}$ $\{B\}$

2. Compute Minimal Cover

$\{C\} \rightarrow \{E\}$ $\{C\} \rightarrow \{D\}$ $\{A,D\} \rightarrow \{B\}$
$\{B\} \rightarrow \{C\}$ $\{A,D\} \rightarrow \{C\}$
$\{B\} \rightarrow \{A\}$

Consider $\{B\} \rightarrow \{C\}$, can we remove this?

Computation #2

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

$\{C\} \rightarrow \{E\}$
$\{C\} \rightarrow \{D\}$
$\{A,D\} \rightarrow \{B\}$
$\{B\} \rightarrow \{C\}$
$\{A,D\} \rightarrow \{C\}$
$\{B\} \rightarrow \{A\}$

Consider $\{A,D\} \rightarrow \{B\}$, can we remove this?

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}

{B} → {A}

{C} → {D}

{B} → {C}

{A,D} → {B}

{A,D} → {C}

Consider {A,D} → {C}, can we remove this?

Computation #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

1. Compute Candidate Key

Ans: {A,D} {A,C} {B}

2. Compute Minimal Cover

{C} → {E}
{B} → {A}
{C} → {D}
{B} → {C}
{A,D} → {B}

Computation #3

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

1. Compute Candidate Key

Ans: $\{A,D\}$ $\{A,C\}$ $\{B\}$

2. Compute Minimal Cover

$\{C\} \rightarrow \{E\}$ $\{C\} \rightarrow \{D\}$ $\{A,D\} \rightarrow \{B\}$
$\{B\} \rightarrow \{A\}$ $\{B\} \rightarrow \{C\}$

3. Compute Canonical Cover

$\{C\} \rightarrow \{D,E\}$ $\{B\} \rightarrow \{A,C\}$ $\{A,D\} \rightarrow \{B\}$

Quiz #1

$R = \{A, B, C, D, E\}$
$\Sigma = \{ \{C\} \rightarrow \{E\}, \{B\} \rightarrow \{E\}, \{B\} \rightarrow \{A\}, \{C,E\} \rightarrow \{D\}, \{B,E\} \rightarrow \{C\}, \{A,D\} \rightarrow \{B\}, \{A,D\} \rightarrow \{C\} \}$

Question

Which of the following is **NOT** a superkey of R with Σ?

Key: {B}, {A,C}, {A,D}
Min Cover: {{C} → {E}, {B} → {A}, {C} → {D}, {B} → {C}, {A,D} → {B}}

	Choice	Comment	
A	{B,E}	*NO: {B,E} ⊇ {B}*	✗
B	{A,C,D}	*NO: {A,C,D} ⊇ {A,C}*	✗
C	{C,D,E}	*YES: not superset of any key*	✓
D	{B}	*NO: {B} ⊇ {B}*	✗

Quiz #2

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

Question

Which of the following is a key of R with Σ?

Key: {B}, {A,C}, {A,D}
Min Cover: {{C} → {E}, {B} → {A}, {C} → {D}, {B} → {C}, {A,D} → {B}}

	Choice	Comment	
A	{B,E}	*NO: {B} is superkey*	✗
B	{A,C,D}	*NO: {A,C}/{A,D} are superkey*	✗
C	{C,D,E}	*NO: not even superkey*	✗
D	{B}	*YES: minimal*	✓

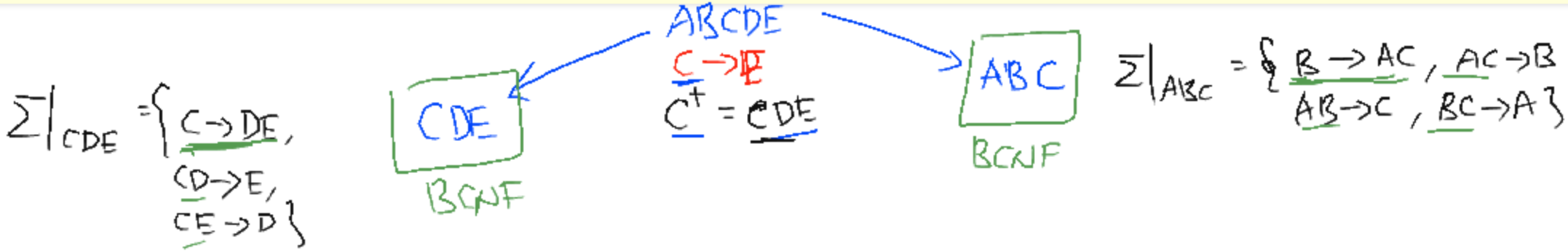
Quiz #3

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

Question

Find one lossless-join decomposition of R with Σ in **BCNF**. Is it dependency preserving?

Key: {B}, {A,C}, {A,D}
Min Cover: {{C} → {E}, {B} → {A}, {C} → {D}, {B} → {C}, {A,D} → {B}}



Quiz #4

R = {A, B, C, D, E}
Σ = { {C} → {E}, {B} → {E}, {B} → {A}, {C,E} → {D}, {B,E} → {C}, {A,D} → {B}, {A,D} → {C} }

Question

Find one lossless-join dependency preserving decomposition of R with Σ in 3NF.

Key: {B}, {A,C}, {A,D}
Min Cover: {{C} → {E}, {B} → {A}, {C} → {D}, {B} → {C}, {A,D} → {B}}

C → DE B → AC AD → B

{C, D, E} {A, B, C} {A, B, D}

Quiz #5

Question

Consider an arbitrary R = {A, B, C, D, E, F} with an unknown Σ. Suppose that R is not in 3NF with respect to Σ. What is the maximum number of keys of R with Σ?

	Choice	Comment	
A	1	*NO*	✗
B	5	*NO*	✗
C	10	*YES*	✓
D	15	*NO*	✗
E	20	*NO*	✗
F	25	*NO*	✗
G	30	*NO*	✗
H	32	*NO*	✗

Quiz #7

Question

Consider an arbitrary relation R. Suppose there are two ***different*** sets of functional dependencies Σ_1 and Σ_2 such that the key of R with Σ_1 is equal to the key of R with Σ_2.

Does it imply that $\Sigma_1 \equiv \Sigma_2$?

$\{A, B, C\}$

$\Sigma_1 = \{A \rightarrow B, A \rightarrow C\}$

$\Sigma_2 = \{A \rightarrow B, B \rightarrow C\}$

$\{AB \rightarrow C\}$

$\{A \rightarrow C\}$

	Choice	Comment	
A	Yes	*NO*	✗
B	No	*YES: R = {A,B,C}, Σ1 = {{A} → {B}}, Σ2 = {{C} → {B}}*	✓

Quiz #7

Question

Consider an arbitrary set of functional dependencies Σ. Further consider **any** two ***minimal cover*** of Σ named Σ_1 and Σ_2.

Does it imply that $\Sigma_1 \cap \Sigma_2 \neq \varnothing$ *(i.e., they share at least one common functional dependency)*?

$\Sigma_1 = A \rightarrow B \quad B \rightarrow C \quad C \rightarrow A$

$\Sigma_2 = A \rightarrow C \quad C \rightarrow B \quad B \rightarrow A$

	Choice	Comment	
A	Yes	*NO*	✗
B	No	*YES: Σ1={{A}→{B},{B}→{C},{C}→{A}}, Σ2={{A}→{C},{C}→{B},{B}→{A}}*	✓

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postgres=# exit
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Press any key to continue . . .
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