COMPUTER SCIENCE

Database Management System

Transaction & Concurrency Control

Lecture_01

Vijay Agarwal sir

TOPICS TO BE COVERED

01 Normal Form Decomposition

02 Transaction Concept

RDBMS Concept

FD Concept & its type

Attribute closure

Key Concept

- Super key
- Candidate key
- Finding Multiple CK

Membership set

Equality b/w 2 FD Set

Finding # Super keys

Closure of FD Set

Minimal [Cannonical Cover]

Properties of Decomposition

1. Lossless Join
2. Dependency Preserving Composition

$\boxed{AB \rightarrow C}$ is Partial Dependency.

if $A \rightarrow C$

OR

if $B \rightarrow C$

Normal Form

1. 1NF
2. 2NF.
3. 3NF.
4. BCNF.

2NF Violation

Proper subset of C.K $\longrightarrow$ Non key Attribute.

its just violation of 2NF.

Check 3NF

Every $X \rightarrow y$ Non Trivial is in 3NF

X: Super key

OR

y: key/Prime Attribute

BCNF

$X \rightarrow y$ Non Trivial FD.

X: Must be Super key.

Normal Forms

3NF

$X \to Y$ Every Non Trivial FD is in 3NF

either X : Super key

OR

Y : Prime Attribute

BCNF

$X \to Y$ Every Non Trivial FD is in BCNF iff

X : Super key.

Normal Forms

R(ABCDE) {A → B, B → C, C → D, D → A}

Candidate key = {AE, BE, CE, DE}

Check 3NF ?

X → y

A → B
B → C
C → D
D → A

X is Not super key
But
y: is Prime/Key Prime Attribute.

R is 3NF
But Not in BCNF.

Normal Forms

Binary Relation (Relation with 2 Attribute) is always in BCNF.

$R(AB)$ $[A \to B]$

Cand. key : [A]

$\underline{A} \to B$

↳ super key

$R(AB)$ $[B \to A]$

Cand. key = (B)

$B \to A$

↓

super key

$R(AB)$ $[A \to B, B \to A]$

Cand. key = (A, B).

$A \to B$, $B \to A$

super key.

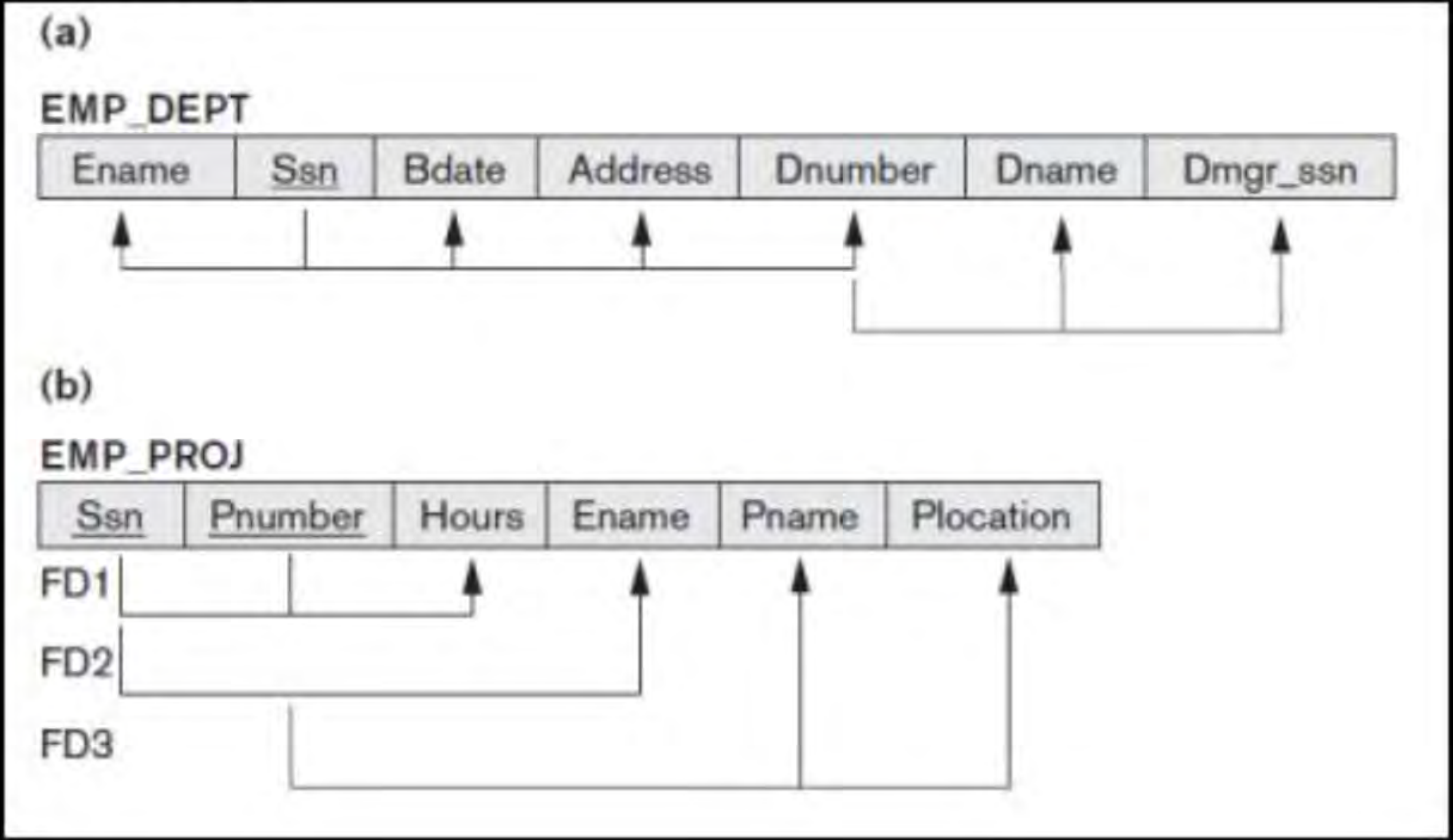
Normal Forms

15.3.5 Second Normal Form

Second normal form (2NF) is based on the concept of *full functional dependency.* A functional dependency $X \rightarrow Y$ is a **full functional dependency** if removal of any attribute A from X means that the dependency does not hold any more; that is, for any attribute $A \varepsilon X$, $(X - \{A\})$ does *not* functionally determine Y. A functional dependency $X \rightarrow Y$ is a **partial dependency** if some attribute $A \varepsilon X$ can be removed from X and the dependency still holds; that is, for some $A \varepsilon X$, $(X - \{A\}) \rightarrow Y$. In Figure 15.3(b), {Ssn, Pnumber} → Hours is a full dependency (neither Ssn → Hours nor Pnumber → Hours holds). However, the dependency {Ssn, Pnumber} → Ename is partial because Ssn → Ename holds.

> **Definition.** A relation schema R is in 2NF if every nonprime attribute A in R is *fully functionally dependent* on the primary key of R.

Figure 15.3


(a)
EMP_DEPT
Ename
Ssn
Bdate
Address
Dnumber
Dname
Dmgr_ssn
(b)
EMP_PROJ
Ssn
Pnumber
Hours
Ename
Pname
Plocation
FD1
FD2
FD3

Normal Forms

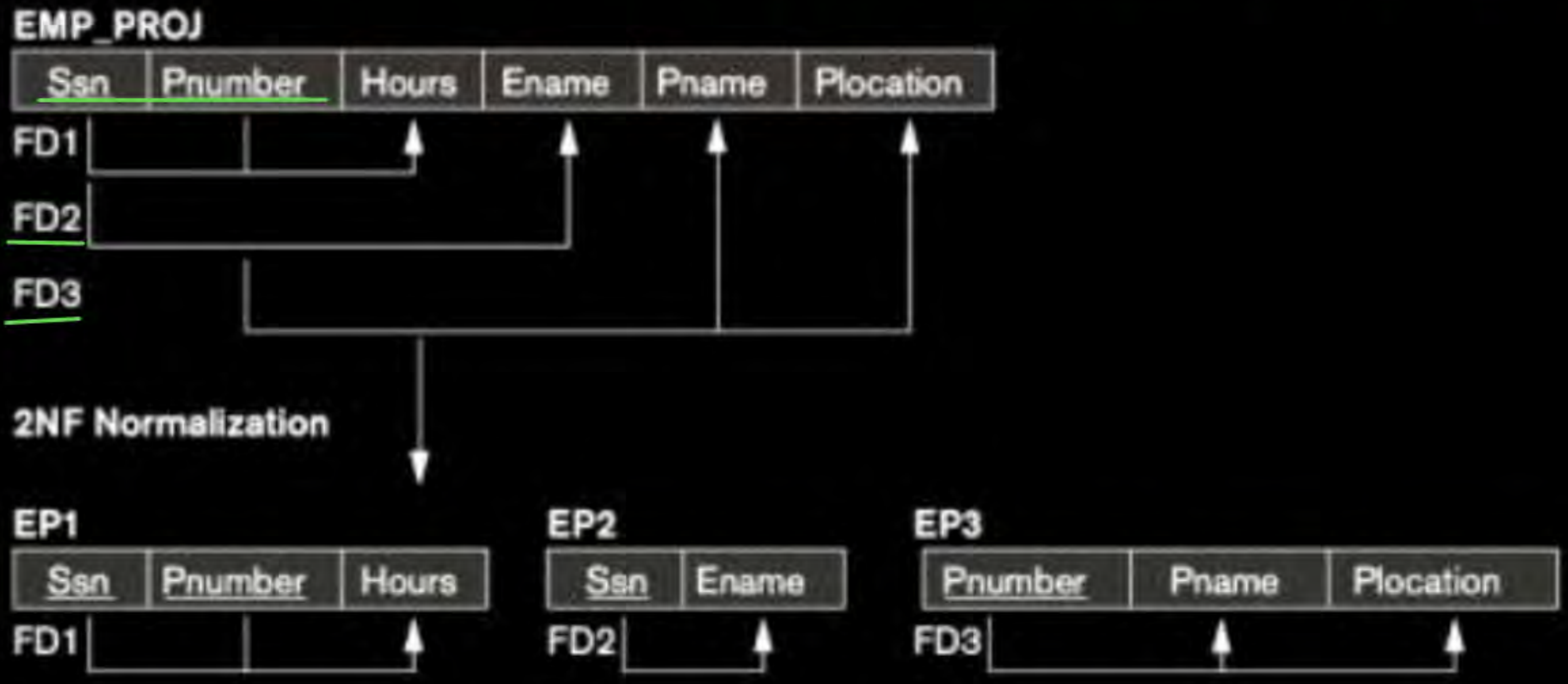
8.17 A functional dependency $\alpha \rightarrow \beta$ is called a partial dependency if there is a proper subset γ of α such that $\gamma \rightarrow \beta$. We say that β is *partially dependent* on α. A relation schema R is in second normal form (2NF) if each attribute A in R meets one of the following criteria:

- It appears in a candidate key.
- It is not partially dependent on a candidate key.

Normal Forms

Second Normal Form

Definition: A relation schema R is in 2NF if every nonprime attribute A in R is fully functionally dependent on the primary key of R.



$R(ABCDEF)\ \{ABC \rightarrow DE,\ DE \rightarrow ABC,\ AB \rightarrow D,\ DE \rightarrow F,\ E \rightarrow C\}$

(i) $ABC \rightarrow D$

(ii) $AE \rightarrow C$

(iii) $AF \rightarrow D$

(iv) $AB \rightarrow D$

(v) $AC \rightarrow D$

(vi) $BC \rightarrow D$

(vii) $DE \rightarrow C$

(vi) $AB \rightarrow F$

Q.

Let R(A, B, C, D, E, P, G) be a relational schema in which the following functional dependencies are known to hold:

$AB \rightarrow CD$, $DE \rightarrow P$, $C \rightarrow E$, $P \rightarrow C$ and $B \rightarrow G$.

The relational schema R is

Cand. key = (AB)

$B \rightarrow G$

Proper subset of CK

Non key Attribute.

(A) In BCNF

(B) In 3NF, but not in BCNF

(C) In 2NF, but not in 3NF

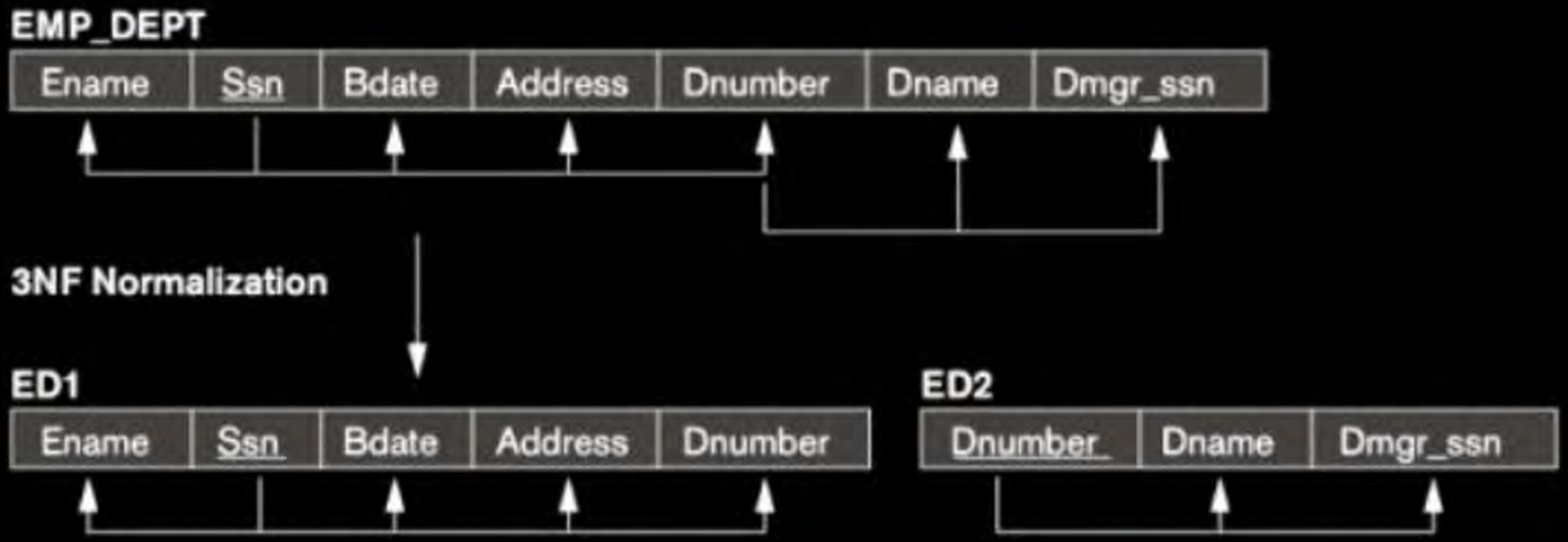
(D) Not in 2NF

Normal Forms

Third Normal Form

Definition: According to Codd's original definition, a relation schema R is in 3NF if it satisfies 2NF and no nonprime attribute of R is transitively dependent on the primary key.

Definition: A relation schema R is in third normal form (3NF) if, whenever a nontrivial functional dependency $X \rightarrow A$ holds in R either (a) X is a superkey of R, or (b) A is a prime attribute of R.


EMP_DEPT
Ename
Ssn
Bdate
Address
Dnumber
Dname
Dmgr_ssn
3NF Normalization
ED1
Ename
Ssn
Bdate
Address
Dnumber
ED2
Dnumber
Dname
Dmgr_ssn

Boyce – Codd Normal Form

Definition: A relation schema R is in BCNF if whenever a nontrivial functional dependency $X \rightarrow A$ holds in R, then X is a superkey of R.

Q. In a relational data model, which one of the following statements is TRUE?

Binary Relⁿ

(A) A relation with only two attributes is always in BCNF.

(B) If all attributes of a relation are prime attributes, then the relation is in BCNF.

(C) Every relation has at least one non-prime attribute.

(D) BCNF decompositions preserve functional dependencies.

Q. Let R(A, B, C, D, E, P, G) be a relational schema in which the following functional dependencies are known to hold:

$AB \rightarrow CD$, $DE \rightarrow P$, $C \rightarrow E$, $P \rightarrow C$ and $B \rightarrow G$.

The relational schema R is

A. In BCNF

B. In 3NF, but not in BCNF

C. In 2NF, but not in 3NF

D. Not in 2NF

Q

Consider the following statements: [MSQ]

S_1: If every attribute is prime attribute in R, then Relation R will always be in BCNF.

S_2: Any Relation with two Attribute is in 3 NF and 2 NF.

S_3: If every key of relation R is a simple candidate key (No composite key) then the relation R not always in NF.

S_4: In BCNF there is always a lossless join and Dependency Preserving Decomposition.

Which of the above statement are incorrect

A S_1

B S_2

C S_3

D S_4

Q

The relation scheme student Performance (name, courseNO, rollNo, grade) has the following functional dependencies:

[2004: 2 Marks]

$X \rightarrow y$

BCNF name, courseNo → grade

BCNF RollNo, courseNo → grade

3NF But Not in BCNF name → rollNo → Prime/key

rollNO → name → Prime/key

Cand.key = [Name CourseNo, RollNo CourseNo]

3NF But Not in BCNF.

The highest normal form of this relation scheme is

A. 2 NF

B. 3 NF

C. BCNF

D. 4 NF

MCQ

In a relational data model, which one of the following statements is TRUE?

GATE-2022-CS: 1M]

(A) A relation with only two attributes is always in BCNF.

(B) If all attributes of a relation are prime attributes, then the relation is in BCNF.

(C) Every relation has at least one non-prime attribute.

(D) BCNF decompositions preserve functional dependencies.

NAT

Consider a relation R(A, B, C, D, E) with the following three functional dependencies.

$AB \to C$; $BC \to D$; $C \to E$;

The number of super keys in the relation R is ___8___ Ans

[GATE-2022-CS: 1M]

Cand. key = (AB)

$\#$ Super key $= 2^{5-2}$

$= 2^3$

$= 8$ Ans

$\underline{AB}\ \underbrace{CDE}_{\downarrow}$

$2^3 = 8$ Ans

MCQ

Consider a relational table R that is in 3 NF, but not in BCNF. Which one of the following statements is TRUE?

[GATE-2020-CS: 2M]

A. R has a non-trivial functional dependency $X \rightarrow A$, where X is not a superkey and A is a prime attribute.

B. R has a non-trivial functional dependency $X \rightarrow A$, where X is not a superkey and A is a non-prime attribute and X is not a proper subset of any key.

C. R has a non-trivial functional dependency $X \rightarrow A$, where X is not a superkey and A is a non-prime attribute and X is a proper subset of some key.

D. A cell in R holds a set instead of an atomic value.

3NF	BCNF
X : Super key ×	X : super key. ×
OR	
Y : key | Prime Attribute	

MCQ

Let the set of functional dependencies $F = \{QR \rightarrow S, R \rightarrow P, S \rightarrow Q\}$ hold on a relation schema X=(PQRS) . X is not in BCNF. Suppose X is decomposed into two schemas Y and Z, where Y=(P R) and Z=(Q R S).

Consider the two statements given below.

I. Both Y and Z are in BCNF

II. Decomposition of X into Y and Z is dependency preserving and lossless

Which of the above statements is/are correct?

[GATE-2019-CS: 2M]

(A) Both I and II

(B) I only

(C) II only

(D) Neither I nor II

Q.

Consider the following four relational schemas. For each schema, all non-trivial functional dependencies are listed. The underlined attributes are the respective primary keys.

Schema I: Registration (<u>rollno</u>, courses)

Field 'courses' is a set-valued attribute containing the set of courses a student has registered for.

Non-trivial functional dependency:

<u>rollno</u> → courses BCNF

Schema II: Registration (<u>rollno, courseid</u>, email)

Non-trivial functional dependencies:

rollno, courseid → email
email → rollno

} 3NF But Not in BCNF

rollno cid, em cid

Schema III: Registration (<u>rollno, courseid</u>, marks, grade)

marks → Grade

Non-trivial functional dependencies:

rollno, courseid → marks, grade

N.K → N.K $\boxed{\text{marks → grade}}$ 2NF But Not in 3NF.

Schema IV: Registration (<u>rollno, courseid</u>, marks, credit)

Non-trivial functional dependencies:

rollno, courseid → credit
$\boxed{\text{courseid → credit}}$

} Not in 2NF

Professional ... → Non key

Which one of the relational schemas above is in 3NF but not in BCNF?

(A) Schema I

(B) Schema II ✓

(C) Schema III

(D) Schema IV

[MCQ: 2018: 2M]

Q. A database of research articles in a journal uses the following schema.

(VOLUME, NUMBER, STARTPAGE, ENDPAGE, TITLE, YEAR, PRICE)

The primary key is (VOLUME, NUMBER, STARTPAGE, ENDPAGE) and the following functional dependencies exist in the schema.

(VOLUME, NUMBER, STARTPAGE, ENDPAGE) → TITLE

(VOLUME, NUMBER) → YEAR

(VOLUME, NUMBER, STARTPAGE, ENDPAGE) → PRICE.

The database is redesigned to use the following schemas.

(VOLUME, NUMBER, STARTPAGE, ENDPAGE, TITLE, PRICE)

(VOLUME, NUMBER, YEAR)

Which of the weakest normal form that the new database satisfies, but the old one does not? [MCQ: 2016: 1M]

(A) 1NF

(C) 2NF

(B) 3NF

(D) BCNF

NAT

Given an instance of the STUDENTS relation as shown below:

Student ID	Student Name	Student Email	Student Age	CPI
2345	Shankar	shankar@math	X	9.4
1287	Swati	swati@ee	19	9.5
7853	Shankar	shankar@cse	19	9.4
9876	Swati	swati@mech	18	9.3
8765	Ganesh	ganesh@civil	19	8.7

For (Student Name, Student Age) to be a key for this instance, the value X should NOT be equal to ____19____.

[GATE-2014-CS: 1M]

NAT

The maximum number of superkeys for the relation schema R (E, F, G, H) with E as the key is ___________.

[GATE-2014-CS: 1M]

MCQ

Given the following two statements:

S1: Every table with two single-valued attributes is in 1 NF, 2 NF, 3 NF and BCNF.

S2: $AB \rightarrow C$, $D \rightarrow E$, $E \rightarrow C$ is a minimal cover for the set of functional dependencies $AB \rightarrow C$, $D \rightarrow E$, $AB \rightarrow E$, $E \rightarrow C$.

Which one of the following is CORRECT?

[GATE-2014-CS: 2M]

A. S1 is TRUE and S2 is FALSE.

B. Both S1 and S2 are TRUE.

C. S1 is FALSE and S2 is TRUE

D. Both S1 and S2 are FALSE.

MCQ

Relation R has eight attributes ABCDEFGH.
Fields of R contain only atomic values.
$F = \{CH \rightarrow G, A \rightarrow BC, B \rightarrow CFH, E \rightarrow A, F \rightarrow EG\}$ is a set of functional dependencies (FDs) so that F^+ is exactly the set of FDs that hold for R.
How many candidate keys does the relation R have?

[GATE-2013-CS: 2M]

(A) 3

(B) 4

(C) 5

(D) 6

MCQ

Relation R has eight attributes ABCDEFGH.
Fields of R contain only atomic values.
$F = \{CH \rightarrow G, A \rightarrow BC, B \rightarrow CFH, E \rightarrow A, F \rightarrow EG\}$ is a set of functional dependencies (FDs) so that F^+ is exactly the set of FDs that hold for R.
The relation R is

[GATE-2013-CS: 2M]

(A) in 1 NF, but not in 2 NF.

(B) in 2 NF, but not in 3 NF.

(C) in 3NF, but not in BCNF.

(D) in BCNF.

MCQ

Which of the following is TRUE?

[GATE-2012-CS: 1M]

(A) Every relation in 3 NF is also in BCNF

(B) A relation R is in 3 NF if every non-prime attribute of R is fully functionally dependent on every key of R

(C) Every relation in BCNF is also in 3 NF

(D) No relation can be in both BCNF and 3 NF

MCQ

Consider the following relational schemes for a library database:

Book (Title, Author, Catalog_no, Publisher, Year, price)

Collection (Title, Author, Catalog_no)

With the following functional dependencies:

I. TitleAuthor $\longrightarrow$ Catalog_no

II. Catalog_no $\longrightarrow$ Title Author Publisher Year

III. Publisher Title Year $\rightarrow$ Price

Assume { Author, Title} is the key for both schemes.

Which of the following statements is true?

[GATE-2008-CS: 2M]

A. Both Book and Collection are in BCNF

B. Both Book and Collection are in 3 NF only

C. Book is in 2 NF and Collection is in 3NF

D. Both Book and Collection are in 2 NF only

MCQ

Let R(A, B, C, D, E, P, G) be a relational schema in which the following functional dependencies are known to hold:

$AB \rightarrow CD$, $DE \rightarrow P$, $C \rightarrow E$, $P \rightarrow C$ and $B \rightarrow G$.

The relational schema R is

[GATE-2008-CS: 2M]

(A) in BCNF

(B) in 3NF, but not in BCNF

(C) in 2 NF, but not in 3 NF

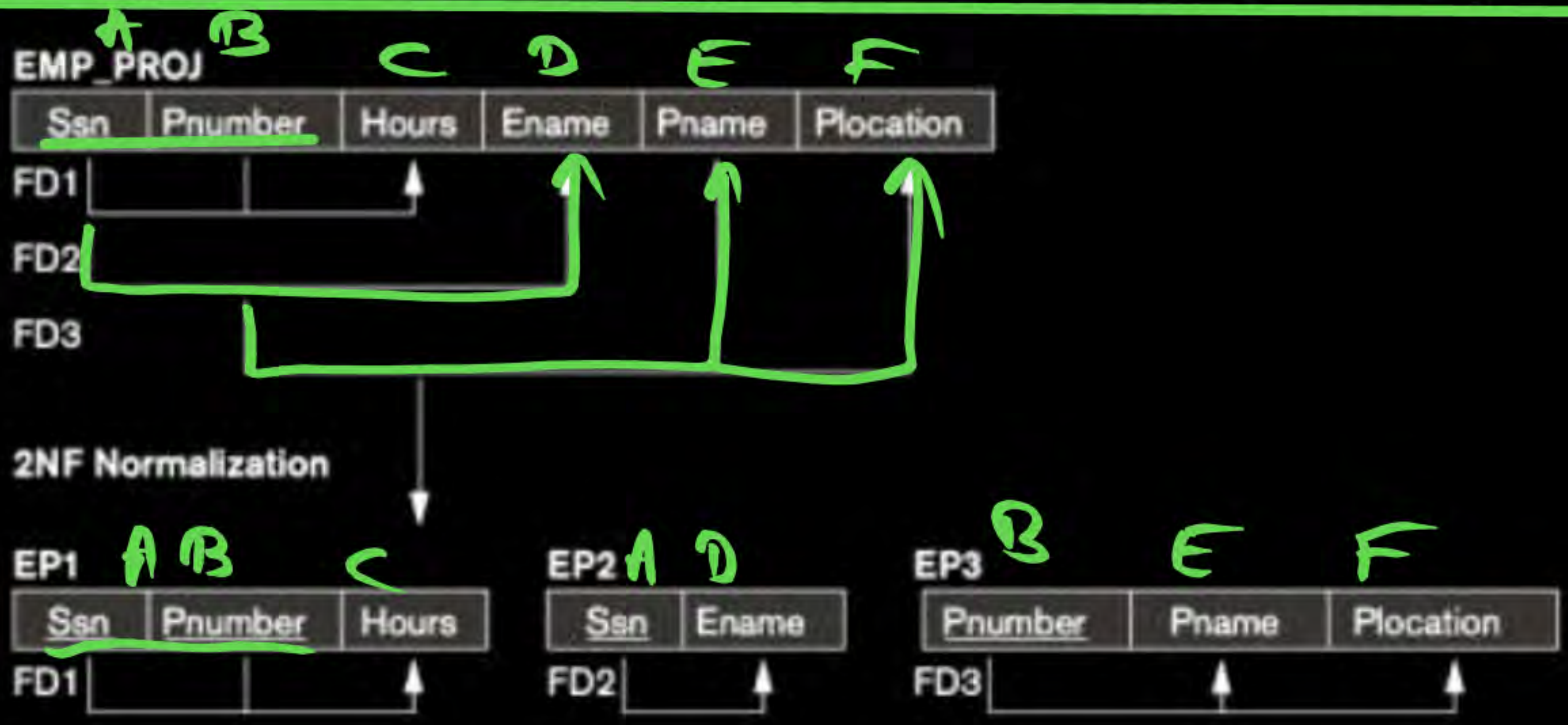
(D) not in 2 NF

Normal Form Decomposition

Normal Forms

Second Normal Form

Definition: A relation schema R is in 2NF if every nonprime attribute A in R is fully functionally dependent on the primary key of R.



2 NF CHECK ?

If this type of FD exists

Proper subset of Candidate key → Non key Attribute

then R Not in 2NF.

AB

Subset

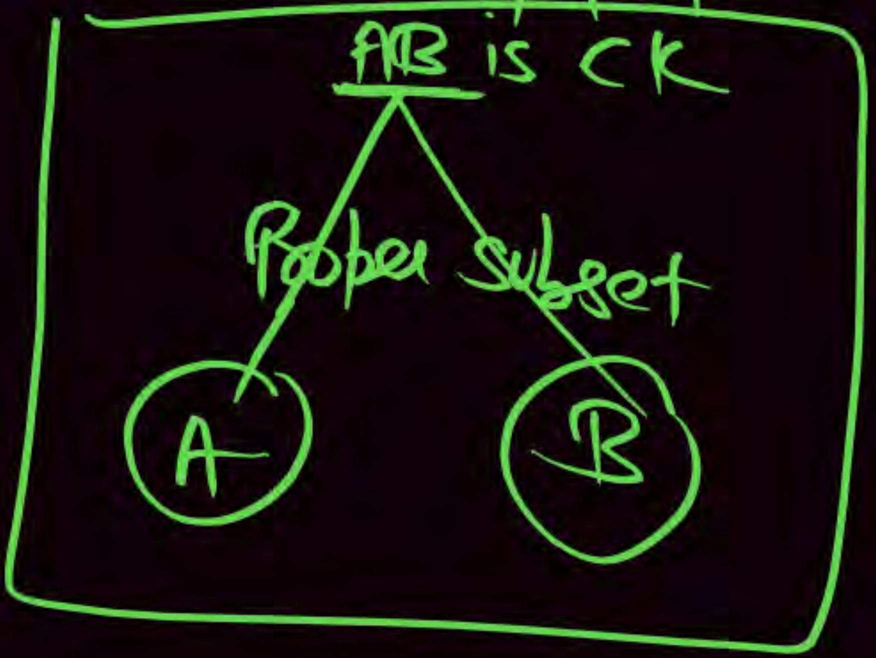
ϕ

A

B

AB

But Proper subset



Proper subset

ABC

AB   BC   AC

A , B, C

&

AB

A   B

A is CK

then No Proper subset

Design Goal	1NF	2NF	3NF	BCNF
0% Redundancy	✗	✗	✗	✓
Lossless Join	✓	✓	✓	✓
Dependency Preserving	✓	✓	✓	May / May Not

2NF Decomposition

Q.1 R(ABCDEFGH) $\{AB \rightarrow C,\ C \rightarrow D,\ B \rightarrow E,\ E \rightarrow F,\ G \rightarrow H\}$

Candidate key = [AB]

Non key Attribute = [C, D, E, F, G, H]

CHECK 2NF ?

$B \longrightarrow E$

Proper subset of C.K Non key Attribute

Violation of 2NF

Not in 2NF

$[B]^+ = [BEFGH]$

2NF Decomposition

R(ABCD~~EFGH~~)

R_1: | A B C D |

R_2: | B E F G H |

2NF + Dep. Preserved + Lossless Join.

Common Attribute

$$R_1(ABCD) \cap R_2(BEFGH) = [B]$$

$$(B)^+ = [BEFGH]$$

Super key of R_2

Lossless Join

2NF Decomposition

Q.2 R(ABCDE) F: [$A \rightarrow B$, $B \rightarrow E$, $C \rightarrow D$]

Decompose it into 2NF.

Candidate key = [AC]

CHECK 2NF ?

$A \rightarrow B$ $C \rightarrow D$

Proper subset of CK → Non key Attribute

Not in 2NF.

2NF Decomposition

$(A)^+ = (ABE)$

$(C)^+ = (CD)$

$\boxed{ABE}$ $\boxed{CD}$

Lossy Join

(No common Attribute)

(Spurious Tuples)

2NF Decomposition

Q.2 R(ABCDE) F: [A $\xrightarrow{①}$ B, B $\xrightarrow{②}$ E, C $\xrightarrow{③}$ D]

Decompose it into 2NF.

Candidate key = [AC]

CHECK 2NF ?

A→B C→D

Proper subset of CK → Non key Attribute

Not in 2NF.

$(A)^+ = (ABE)$

$(C)^+ = (CD)$

2NF Decomposition

R(ABCDE)

R_1: AC

R_2: ABE

R_3: CD

2NF + Lossless + D.P.

2NF Decomposition

Q.3 R (ABCDEFGHIJ) {AB→C, BD→EF, AD→GH, A→I, H→J}

Candidate key = [ABD]

Non key Attribute = [C, E, F, G, H, I, J]

CHECK 2NF ?

AB → C
BD → EF
AD → GH
A → I

Violation of 2NF

$(AB)^+ = [ABCI]$

$(BD)^+ = (BDEF)$

$(AD)^+ = [ADGHIJ]$

$(A)^+ = AI$

2NF Decomposition

R(AB~~C~~D~~EFGHIJ~~)

$\boxed{ABD}$ $\boxed{ABCI}$ $\boxed{BDEF}$ $\boxed{ADGHIJ}$

Not in 2NF

$\boxed{AI}$

2NF Decomposition

Q.3 R (ABCDEFGHIJ) $\{AB \rightarrow C,\ BD \rightarrow EF,\ AD \rightarrow GH,\ A \rightarrow I,\ H \rightarrow J\}$

R_2

ABCI

$AB \rightarrow C$

$A \rightarrow I$

ABC

AI

1

R_4

ADGHIJ

$AD \rightarrow GH$ ✓

$H \rightarrow J$

$A \rightarrow I$ ✗

ADGHJ

AI

2

2NF Decomposition

R(ABCDEFGHIJ)

R_1: ABD

3

R_2: ABCI

R_3: BDEF

4

R_4: ADGHIJ

R_5: AI

Not in 2NF.

2NF

+ Lossless

+ Dep. Preserving.

2NF Decomposition

Q.4 R(ABCDEF) {AB → C, C → D, B → EF}

Candidate key = [AB]

Non key Attribute = [C, D, E, F]

CHECK 2NF ?

B → EF

Proper subset of Non key — Non key Attribute

Not in 2NF

$(B)^+ = (BEF)$

2NF Decomposition

R(ABCD~~EF~~)

R1	R2
AB C D	BEF

2NF + Lossless + D.P

2NF Decomposition

Q.5 R(ABCDEFGH) {AB → C, C → D, B → E, E → F, A → GH}

Candidate key = (AB)

Non key Attribute = [C, D, E, F, G, H]

CHECK 2NF ?

$$\left.\begin{array}{l} B \to E \\ A \to GH \end{array}\right\}$$

Violation of 2NF.

$[B]^+ = [BEF]$

$[A]^+ = [AGH]$

2NF Decomposition

R(ABCD~~EFGH~~)

R_1	R_2	R_3
ABCD	BEF	AGH

2NF + lossless + D.P

$R_1(ABCD)$ $R_2(BEF)$ $R_3(AGH)$

$R_1(ABCD) \cap R_2(BEF) = B.$

$(B)^+ = (BEF)$ Super key of R_2

$R_{12}(ABCDEF) \cap R_3(AGH) = A$

$(A)^+ = (AGH)$ Super key of R_3

Lossless Join

2NF Decomposition.

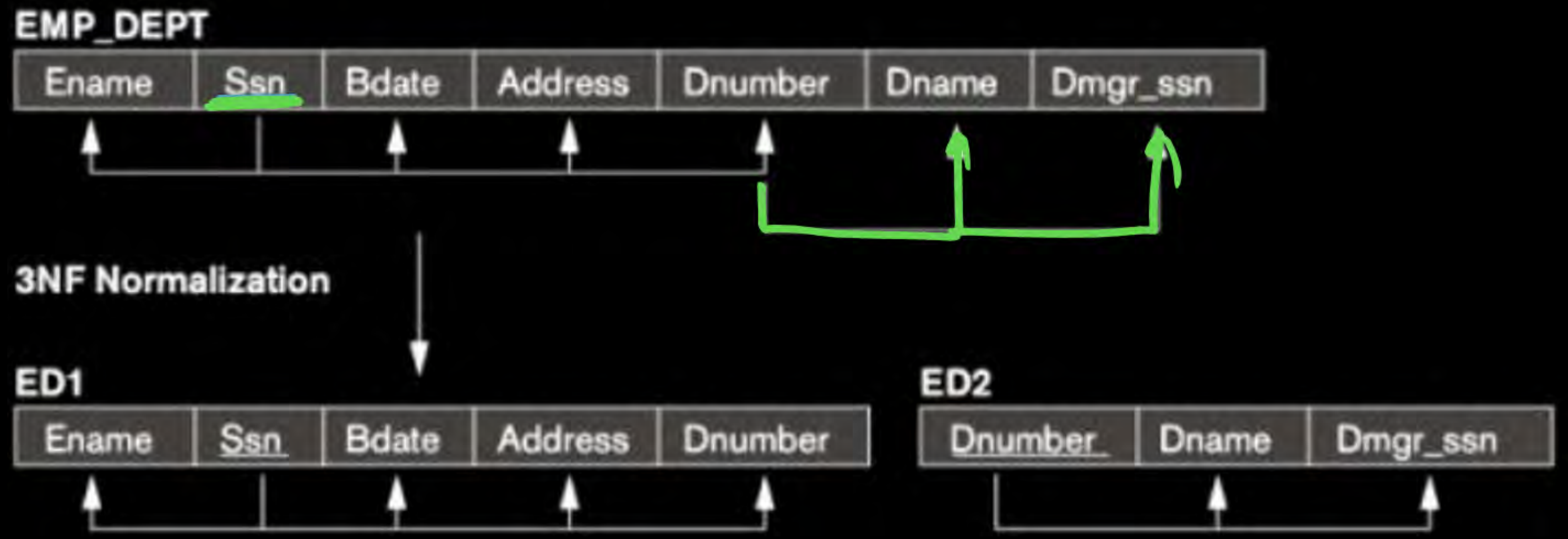
Step 1 Minimal Cover.

Normal Forms

Third Normal Form

Definition: According to Codd's original definition, a relation schema R is in 3NF if it satisfies 2NF and no nonprime attribute of R is transitively dependent on the primary key.

Definition: A relation schema R is in third normal form (3NF) if, whenever a nontrivial functional dependency $X \rightarrow A$ holds in R either (a) X is a superkey of R, or (b) A is a prime attribute of R.


EMP_DEPT
Ename
Ssn
Bdate
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Dnumber
Dname
Dmgr_ssn
3NF Normalization
ED1
Ename
Ssn
Bdate
Address
Dnumber
ED2
Dnumber
Dname
Dmgr_ssn

3NF Decomposition

$A \to C$

Q.1 R(ABC) [A → B, B → C]

Candidate key = [A]

Non key Attribute = [B, C]

CHECK 2NF ?

R is in 2NF.

① CHECK 3NF ?

$B \to C$

Non key Attribute → Non key Attribute

Not in 3NF

② CHECK 3NF ?

$A \to B \to C$

Non Prime

Non key Attribute transitive determine by C.K

Not in 3NF

③ CHECK 3NF ?

X: Super key

OR

y: Prime/key Attribute

A→B; A is super key

B→C; B is Not Super key

C is Not Prime Attr

Not in 3NF

3NF Decomposition

Q.1 R(ABC) $[A \rightarrow B, B \rightarrow C]$

Candidate key = {A}

Non key Attribute = {B, C}

Check 3NF ?

$B \rightarrow C$

B Not Super key

C is Not key / Not Prime Attribute

So R Not in 3NF

3NF Decomposition.

3NF violation

$B \rightarrow C$

A	B

B	C

R is in 3NF

+ Dep. Preserved

+ Lossless

3NF Decomposition

Q.1 R(ABC) [$A \rightarrow B$, $B \rightarrow C$]

R(ABC)

C.K : [A]

A	B	C
1	b_1	x
2	b_1	x
3	b_1	x
4	b_1	x
5	b_1	x
6	c_1	y
7	c_1	y
8	c_1	y
9	c_1	y
10	c_1	y
11	c_1	y

3NF Decomposition.

R_1

A	B

R_2

B	C

R_1(AB)

A	B
1	b_1
2	b_1
3	b_1
4	b_1
5	b_1
6	c_1
7	c_1
8	c_1
9	c_1
10	c_1
11	c_1

R_2(BC)

B	C
b_1	x
c_1	y

3NF Decomposition

Q.2 $R(ABCDEF) \quad [AB \rightarrow C, C \rightarrow D, D \rightarrow E, E \rightarrow F]$

3NF Decomposition

Q.3 $R(ABCDEFGHIJ)\ \{AB \to C,\ BD \to EF,\ AD \to GH,\ A \to I,\ H \to J\}$

3NF Decomposition

Q.4 R (ABCD) {AB→CD, D→A}

3NF Decomposition

Q.5 R (ABCDEFGH) $\{A \rightarrow BC, B \rightarrow DEF, DE \rightarrow AGH\}$

Q.6 $R(ABCDE)$ $\{AB \rightarrow C, C \rightarrow D, B \rightarrow E\}$

Decompose into 2NF, 3NF, BCNF

THANK YOU!