COMPUTER SCIENCE

Database Management System

FD's & Normalization
Normal Forms-3

Lecture_11

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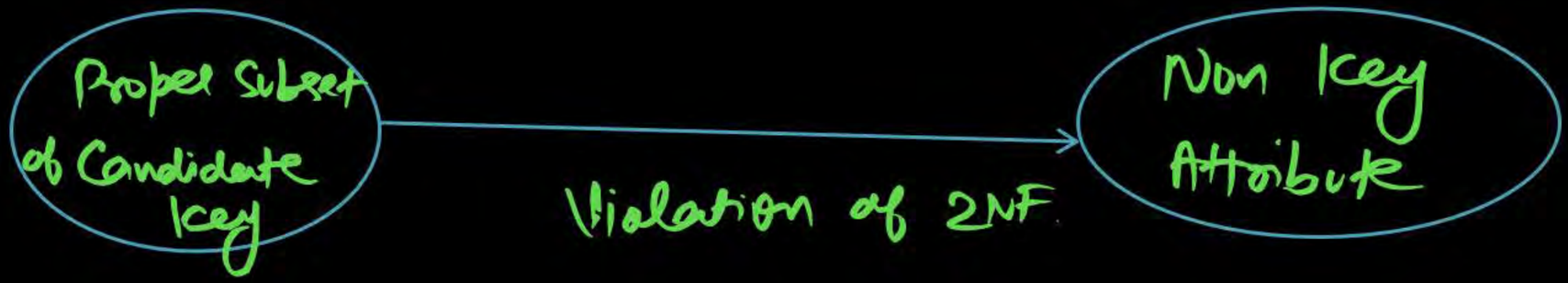
TOPICS
TO BE
COVERED
01
2NF, 3NF , BCNF
02
NF Decomposition

2NF


Proper Subset of Candidate Key
Violation of 2NF
Non Key Attribute

3NF

R is in 2NF.

&

3NF (OR) Not

$X \rightarrow Y$ X: Super key

(OR)

Y: key / Prime Attribute

3NF [Case I & II] Not allowed.

BCNF

&

OR

BCNF

Every $X \to Y$ Non Trivial FD

X : Super Key.

Q. In a relational data model, which one of the following statements is TRUE? [GATE 2022].

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. Which of the following statement is/are true?

A. Second normal form (2NF) have transitive dependency.

B. No relation can be in both BCNF and 3NF.

C. Second normal form(2NF) does not have partial dependency.

D. In BCNF lossless join & dependency – preserving decomposition is always possible.

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]

name, courseNo → grade

RollNo, courseNo → grade

name → rollNo

rollNO → name

The highest normal form of this relation scheme is

A 2 NF

B 3 NF

C BCNF

D 4 NF

Normal Form Decomposition

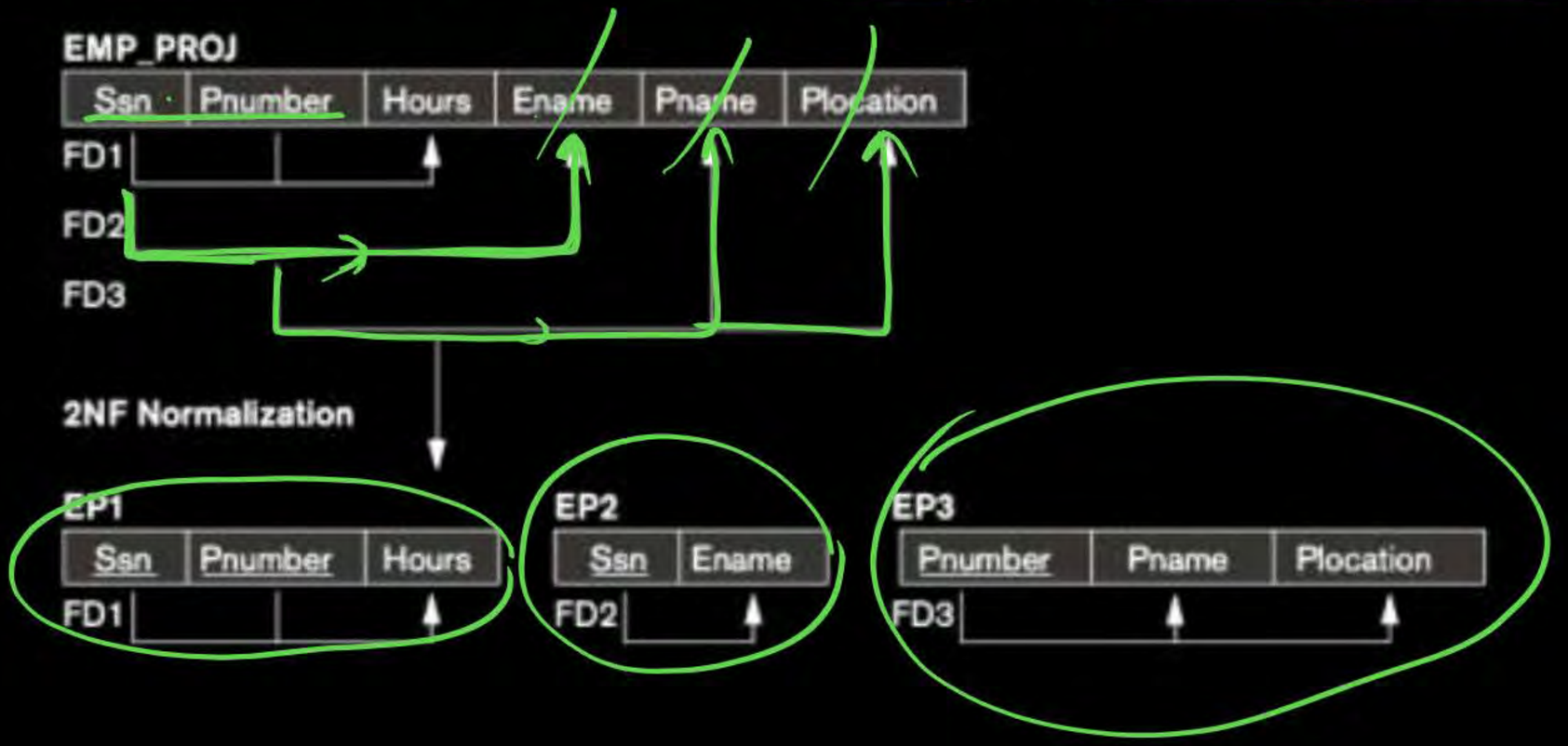
Normal Forms

Design Goal	1NF	2NF	3NF	BCNF
0% Redundancy	No	No	No	YES (But Subset from MVFD $X \to\to Y$)
Lossless Join	YES	YES	YES	YES
Dependency Preserving	YES	YES	YES	May / may Not

Normal Forms

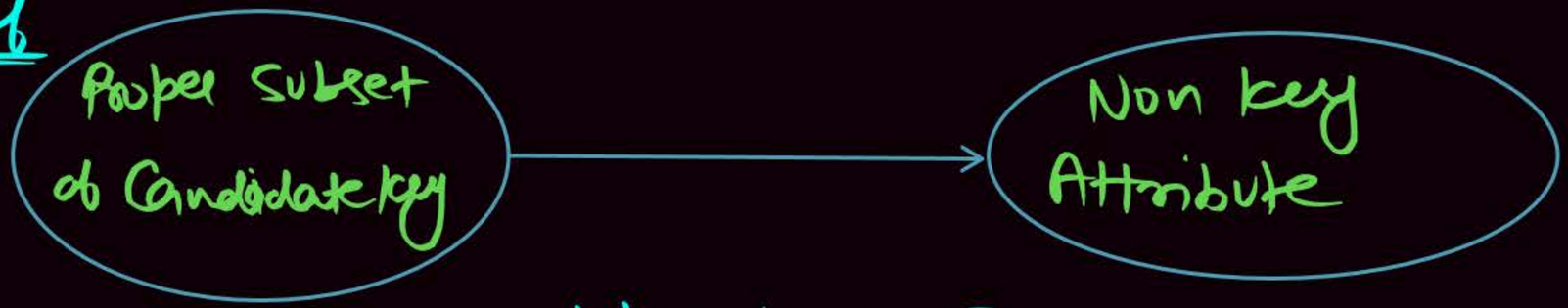
Second Normal Form

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: ① First Find Candidate keys.
② then Write all Non Prime / Non key Attribute

If



its Violation of 2NF.

Not in 2NF

2NF Decomposition

$(x)^+ = [\ldots]$

2NF Decomposition

Q-1

R(ABCDEF) {AB → C, C → D, B → EF}

2NF Decomposition

Candidate key = [AB]

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

$[B]^+ = [BEF]$

R(ABCDEF)

Check 2NF ?

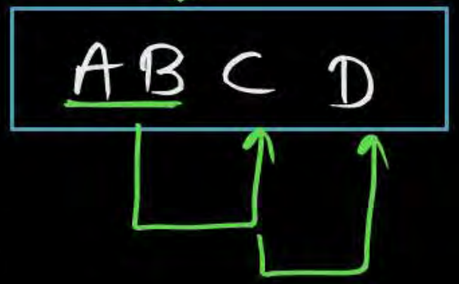
B → EF

Proper Subset of Candidate key

Non key Attribute

R is Not in 2NF.

R_1



R_2

2NF Decomposition

Q.1 $R(ABCDEF)\ \{AB \xrightarrow{R_1} C,\ C \xrightarrow{R_1} D,\ B \xrightarrow{R_2} EF\}$

2NF Decomposition.

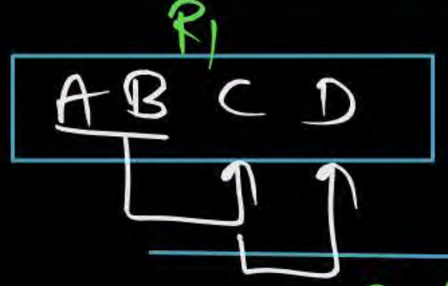
$R_1(ABCD) \cap R_2(BEF] = B$

$(B]^+ = [BEF]$ Subset key of R_2.

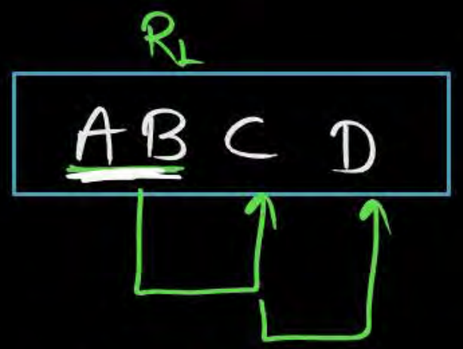
$(B]^+ = [BEF]$

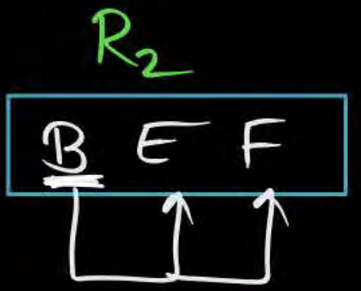
$R(ABCDEF)$

Lossless Join



Dependency Preserved





$\therefore$

2NF Decomposition

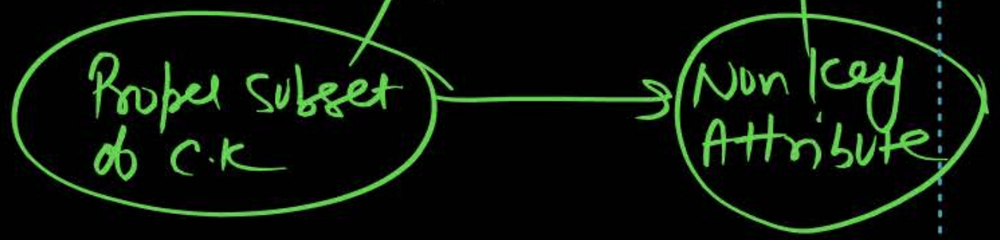
Q.2 $R(ABCDEFGH)\ \{AB \xrightarrow{R_1} C,\ C \xrightarrow{R_1} D,\ B \xrightarrow{R_2} E,\ E \xrightarrow{R_2} F,\ A \xrightarrow{R_3} GH\}$

Candidate key = [AB]

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

CHECK 2NF ?

$B \to E$. $A \to GH$



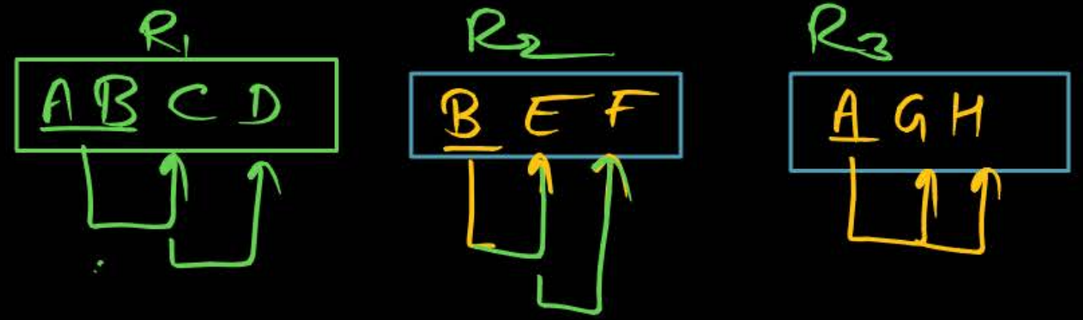
R is Not in 2NF

2NF Decomposition:

$(B)^+ = [BEF]$

$(A)^+ = [AGH]$

R(ABCDEFGH)



2NF Decomposition

Q.2 R(ABCDEFGH) {AB → C, C → D, B → E, E → F, A → GH}

R1 R1 R2 R2 R3

Candidate key = [AB]

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

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

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

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

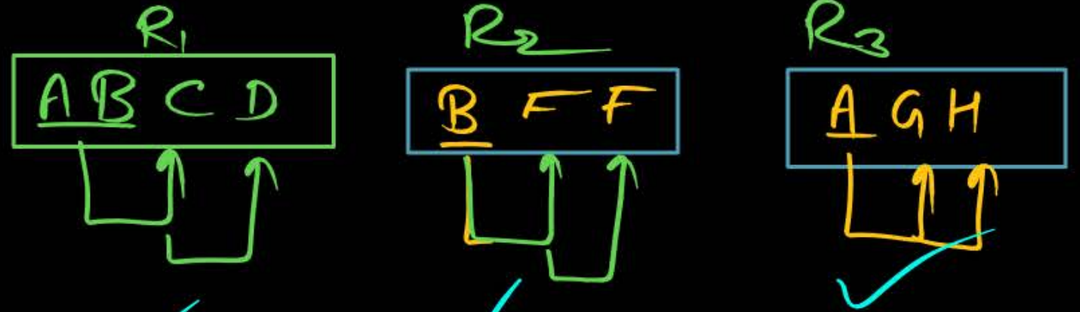
$(A)^+ = [AGH]$ Super key of R_3

Lossless Join

2NF Decomposition:

$(B)^+ = [BEF]$ R(ABCDEFGH)

$(A)^+ = [AGH]$



Dependency Preserved.

2NF Decomposition

Q.3 R(ABCDE) F: [A → B, B → E, C → D]

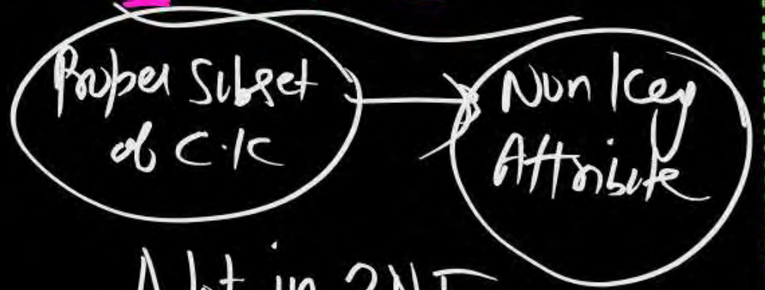
Decompose it into 2NF.

Candidate key = [AC]

Non key Attribute = [B, D, E]

Check 2NF ?

A → B, C → D



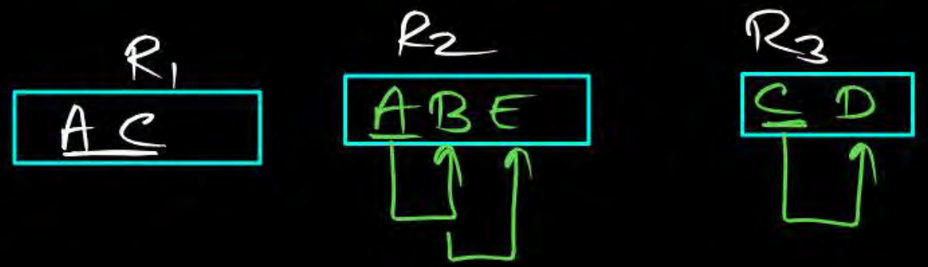
Not in 2NF

2NF Decomposition:

$(A)^+ = [ABE]$

$(C)^+ = [CD]$

R(A B C D E)



2NF Decomposition

Q.3 R(ABCDE) F: [A → B, B → E, C → D] ✓

Decompose it into 2NF.

2NF Decomposition:

$(A)^+ = [ABE]$

$(C)^+ = [CD]$

R(A B C D E)

R_1 AC

R_2 ABE

R_3 CD

Dependency Preserved

Why $R_1(AC)$ will take ?

Bcz if $R_2(ABE) \cap R_3(CD) = \phi$

No Common Attribute.

(Extra tuples)

Lossy Join Because of Spurious Tuples

∴ So we are taking original candidate key (AC) in One Separate Relation also $R_1(AC)$

$R_1(AC) \cap R_2(ABE) = [A]^+ = [ABE]$ subset key of R_2

$R_2(ABEC) \cap R_3(CD) = (C)^+ = [CD]$ subset key of R_3

⇒ Lossless

2NF Decomposition

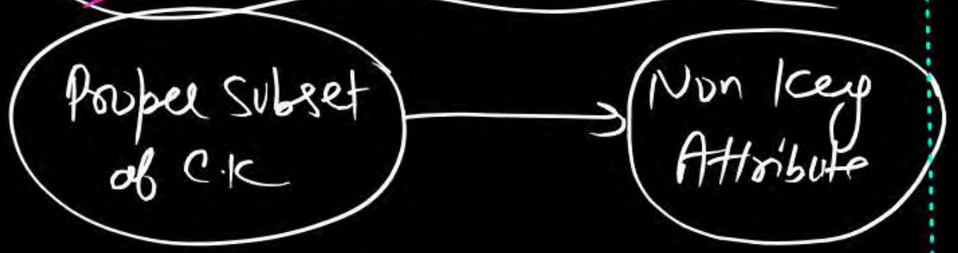
Q.4 $R(ABCDEFG)\ \{AB \rightarrow C, C \rightarrow D, B \rightarrow E, B \rightarrow F, A \rightarrow G\}$

Candidate key = [AB]

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

Check 2NF ?

$B \rightarrow E,\ B \rightarrow F,\ A \rightarrow G$



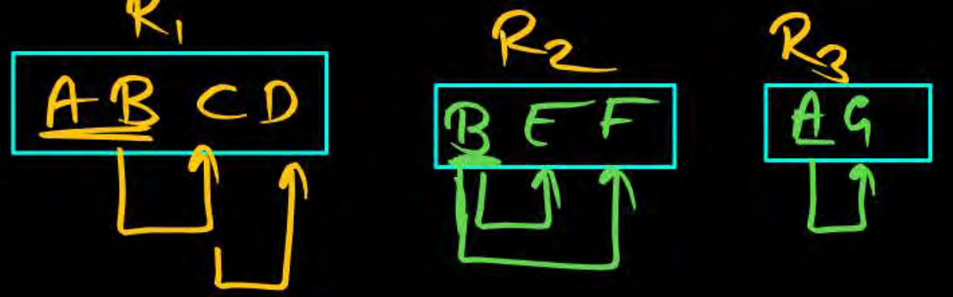
Not in 2NF.

2NF Decomposition

$(B)^+ = (BEF)$

$(A)^+ = (AG)$

R(ABCDEFG)



2NF Decomposition

Q.4 R(ABCDEFG) {AB → C, C → D, B → E, B → F, A → G}

$R_1(ABCD) \cap R_2(BEF) = (B)^+ = (BEF)$ Subset key of R_2

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

$(A)^+ = (AG)$ Subset key of R_3

Lossless Join

AB → C ✓ R_1
C → D ✓ R_1
B → E ✓ R_2
B → F ✓ R_2
A → G ✓ R_3

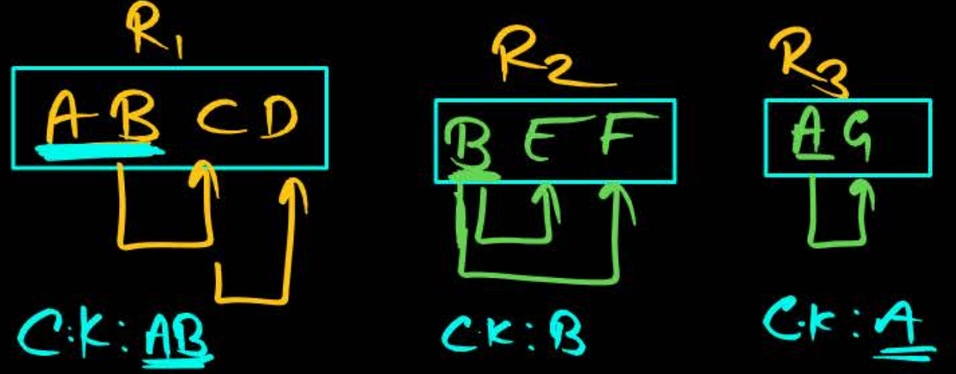
& Dependency Preserved

2NF Decomposition

$(B)^+ = (BEF)$

$(A)^+ = (AG)$

R(ABCDEFG)



2NF Decomposition

Q.5 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

Proper Subset of Candidate key → Non key Attribute

Not in 2NF

2NF Decomposition

$(AB)^+ = [ABCI]$

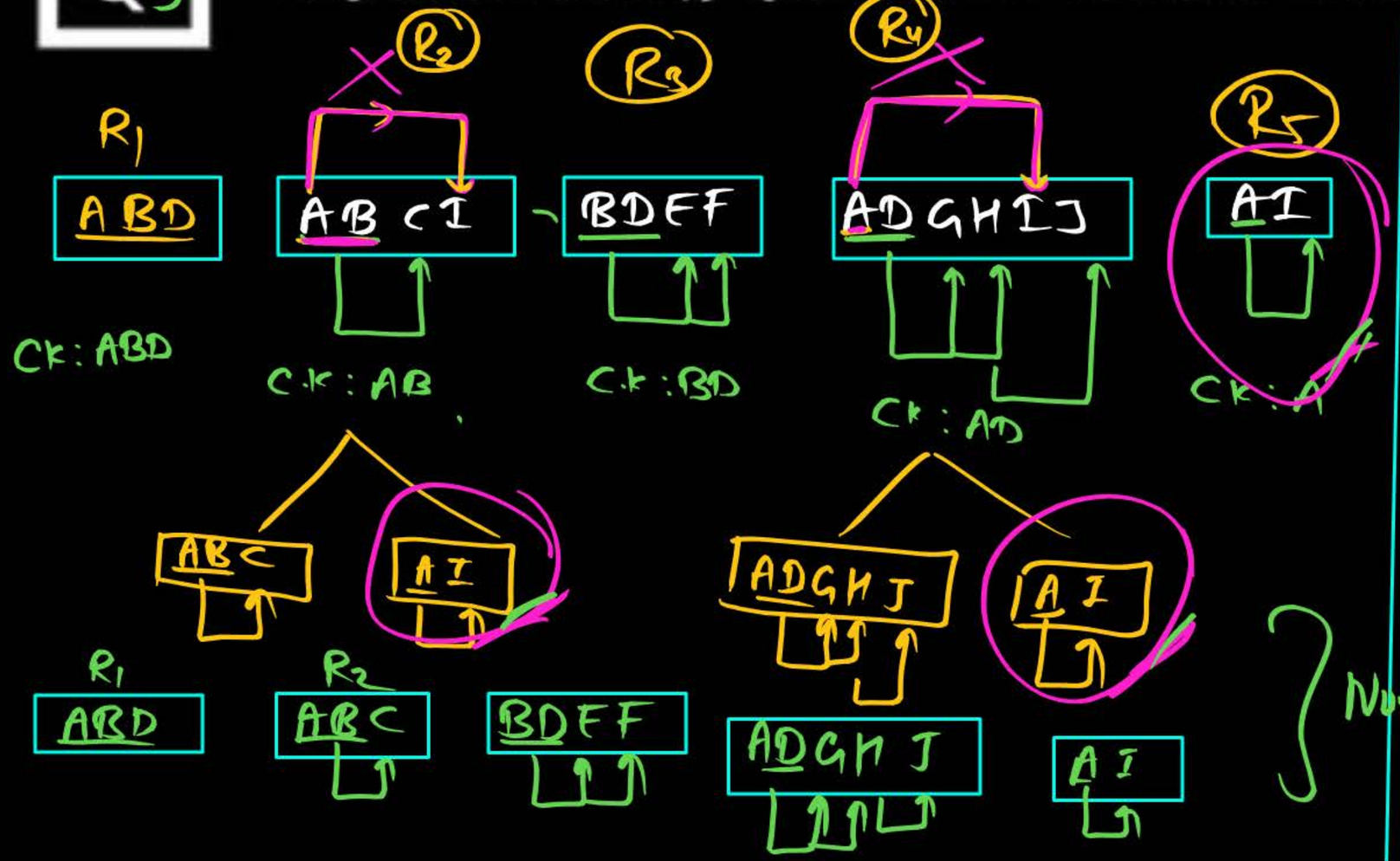
$(BD)^+ = [BDEF]$

$(AD)^+ = [ADGHIJ]$

$(A)^+ = [AI]$

2NF Decomposition

Q.5 R (ABCDEFGHIJ) {AB→C, BD→EF, AD→GH, A→I, H→J}



2NF Decomposition

$(AB)^+ = [ABCI]$

$(BD)^+ = (BDEF)$

$(AD)^+ = [ADGHIJ]$

$(A] = [AI]$

R(ABCDEFGHIJ)

? Now 2NF + lossless + Dep Preserved.

OR

Every Non Trivial $X \rightarrow Y$ FD

X: Super key

OR

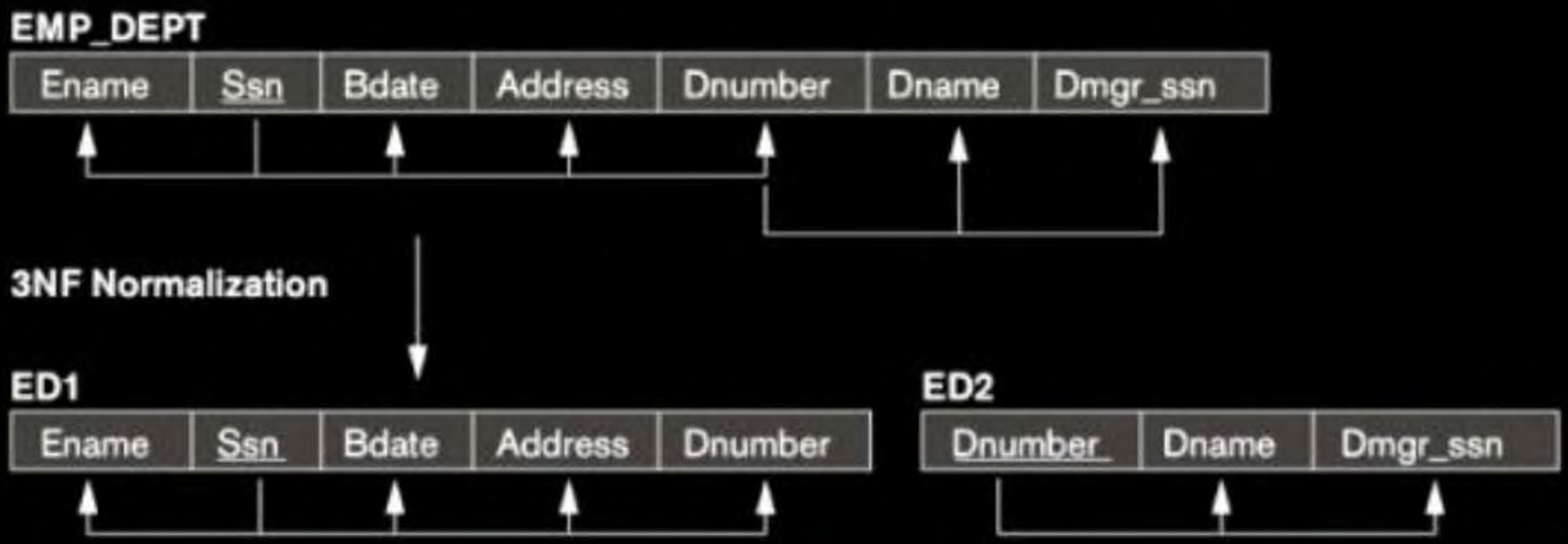
Y: Key / Prime Attribute.

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

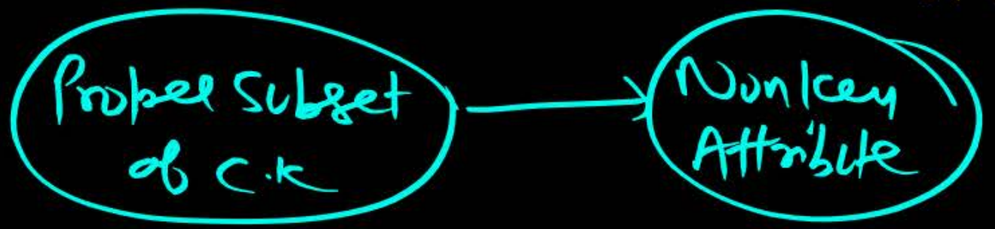
3NF Decomposition

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

Candidate key = [A]

Non key Attribute = [B, C]

Check 2NF ?



No such type of FD exist

R is in 2NF

Check 3NF ?

$B \rightarrow C$

B: Non key Attribute

C: Non key Attribute

R Not in 3NF.

3NF Decomposition

Directly 3NF checking

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

Candidate key = [A]

Non key Attribute = [B, C].

Check 3NF ?

either $X \to Y$

X: Super key

OR

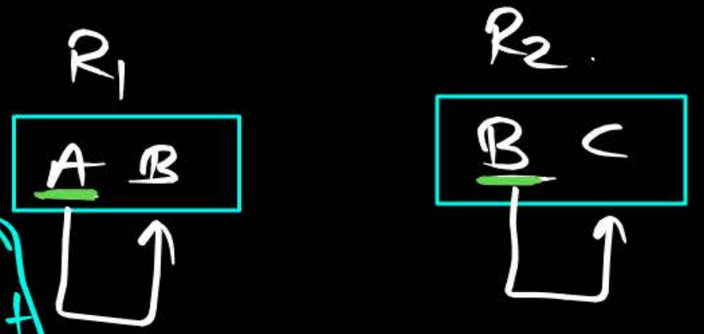
Y: Prime key Attribute

$A \to B$ ✓ 3NF [A is super key]

$B \to C$ ✗ 3NF [B is Not super key OR C is Not key Attribute]

Not in 3NF.

3NF Decomposition:



3NF + Lossless + D.P

$R_1(AB) \cap R_2(BC) = B$

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

Lossless Join.

✓ $A \to B$ in R_1

✓ $B \to C$ in R_2

} Dep. Preserved

3NF Decomposition

Q R(ABC) [A → B, B → C]

R(ABC)

$R_1(AB) \cap R_2(BC) = (B)^+ = (BC)$ Superkey of R

Lossless

R is in 3NF + Lossless + D.P.

A → B, B → C

A	B	C
1	b_1	c_2
2	b_1	c_2
3	b_1	c_2
4	b_1	c_2
5	b_1	c_2
6	b_4	c_7
7	b_4	c_7
8	b_4	c_7
9	b_4	c_7
10	b_4	c_7
11	b_4	c_7

Assume 1 lac Tuple.

3NF Decomposition

$R_1(AB)$

A	B
1	b_1
2	b_1
3	b_1
4	b_1
5	b_1
6	b_4
7	b_4
8	b_4
9	b_4
10	b_4
11	b_4

$R_2(BC)$

B	C
b_1	c_2
b_4	c_7

Lossless

3NF Decomposition

Q2 $R(ABCDEF) \quad [AB \xrightarrow{R_1} C, C \xrightarrow{R_2} D, D \xrightarrow{R_3} E, E \xrightarrow{R_4} F]$

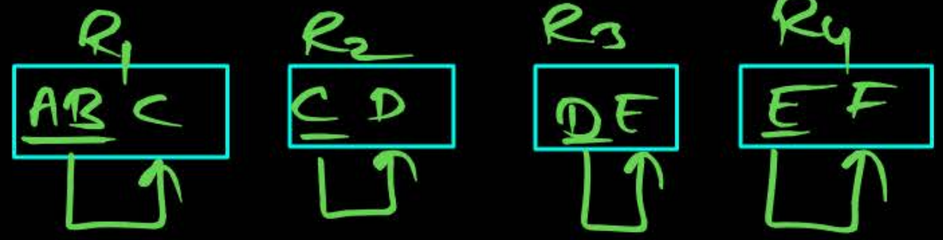
Candidate key = {AB}

Non key Attribute = {C, D, E, F}

Check 3NF

$C \rightarrow D$
$D \rightarrow E$
$E \rightarrow F$
} Violate 3NF

3NF Decomposition



3NF + Lossless Join
+ Dep. Preserved.

3NF Decomposition

3NF Decomposition Directly

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

Candidate key = ABD

Check 3NF ?

AB→C

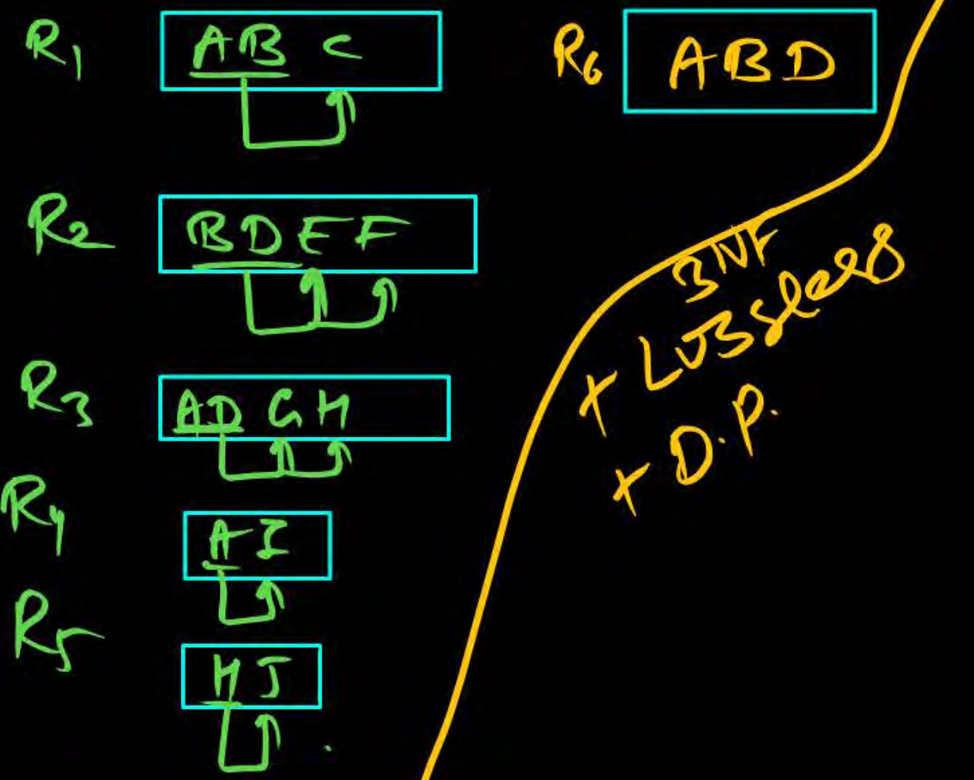
BD→EF

AD→GH

A→I

H→J

3NF Decomposition.



3NF Decomposition

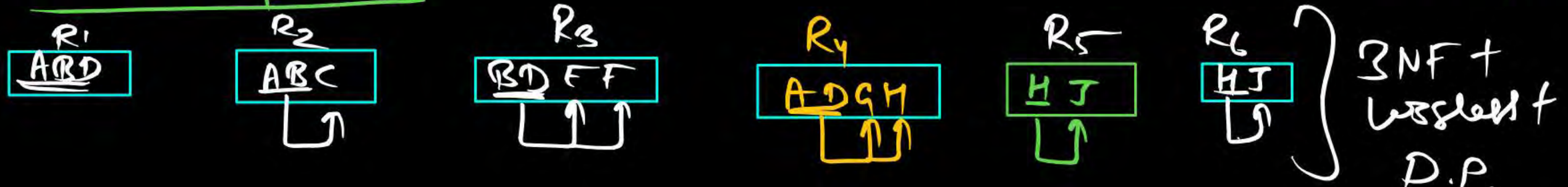
OR

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

2NF Decomposition

2NF But Not in 3NF (∵ H→J (H is Not key & J is Not Prime Attribute)

3NF Decomposition



3NF Decomposition

Q.4 R (ABCD) {AB→CD, D→A}

Candidate key = [AB, DB]

Check 2NF ?

D → A

D is Proper Subset of C.K — But — A is key/Prime Attribute

So No Violation of 2NF

R is in 2NF.

Check 3NF

AB → CD

D → A

D: key, A: key

R is in 3NF.

3NF Decomposition

Directly 3NF

Q.4 R (ABCD) {AB→CD, D→A}

Candidate key = [AB, DB]

Check 3NF

AB→CD ✓ 3NF (AB is Super key)

D→A ✓ 3NF (D is Not Super key But A is key/Prime Attribute)

So R is in 3NF

3NF Decomposition

Q

R (ABCDEFGH) {A→BC, B→DEF, DE→AGH}

Q

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

Decompose into 2NF, 3NF, BCNF

Q

Relation R is decomposed using a set of functional dependencies, F, and relation S is decomposed using another set of functional dependencies, G. One decomposition is definitely BCNF, the other is definitely 3NF, but it is not know which is which. To make a guaranteed identification, which one of the following tests should be used on the decompositions? (Assume that the closures of F and G are available).

[2002: 2 Marks]

A Dependency-preservation

B Lossless-join

C BCNF definition

D 3 NF definition

Q

Which of the following relational schema with given FD's follows is/are in BCNF?

A. R(ABCDE) and FD's are $\{A \rightarrow B, B \rightarrow C, C \rightarrow D, D \rightarrow E, C \rightarrow A\}$

B. R(ABCDE) and FD's are $\{A \rightarrow B, C \rightarrow D, D \rightarrow E\}$

C. R(ABCD) and FD's are $\{A \rightarrow B, B \rightarrow C, C \rightarrow D, D \rightarrow A\}$

D. R(ABCD) and FD's are $\{A \rightarrow B, B \rightarrow C, C \rightarrow A\}$

Q

Consider the following Relation:

R(ABCDEFG) with FD set of Relation R {A → B, C → D, E → FG}. What is the minimum number of relations required to decompose into BCNF which satisfy lossless join and Dependency preserving decomposition _____

Q

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

[2004: 2 Marks]

name, courseNo → grade

RollNo, courseNo → grade

name → rollNo

rollNO → name

The highest normal form of this relation scheme is

A 2 NF

B 3 NF

C BCNF

D 4 NF

Q.

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.

[MCQ: 2013: 2M]

The relation R is

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

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

C. in 3NF, but not in BCNF.

D. in BCNF.

Q.

Given an instance of the STUDENTS relation as shown below:

StudentID	StudentName	StudentEmail	StudentAge	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

Key Must be Unique.

For (StudentName, StudentAge) to be a key for this instance, the value X should NOT be equal to 19. Ans

[NAT: 2014: 1M]

Key Must be Unique.

AB is key for this Relation R.

R(AB)

A	B
1	4
2	5
3	6
1	5

Q.① Can A become key ?

Q.② Can B become key ?

Sol¹ No

Sol² No

Q.

Given the following two statements:

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

[MCQ: 2014: 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.

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:

rollno → courses

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

Non-trivial functional dependencies:

rollno, courseid → email

email → rollno

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

Non-trivial functional dependencies:

rollno, courseid → marks, grade

marks → grade

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

Non-trivial functional dependencies:

rollno, courseid → credit

courseid → credit

Which one of the relational schemas above is in 3NF but not in BCNF? [MCQ: 2018: 2M]

(A) Schema I

(B) Schema II

(C) Schema III

(D) Schema IV

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) $\rightarrow$ TITLE

(VOLUME, NUMBER) $\rightarrow$ YEAR

(VOLUME, NUMBER, STARTPAGE, ENDPAGE) $\rightarrow$ 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

(B) 3NF

(C) 2NF

(D) BCNF

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

[MCQ: 2020-2M]

A. R has a nontrivial 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.

B. R has a nontrivial 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. A cell in R holds a set instead of an atomic value.

D. R has a nontrivial functional dependency $X \rightarrow A$, where X is not a superkey and A is a prime attribute.

Q.

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

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

The number of superkeys in the relation R is _____.

[NAT:2022-1M]

Any Doubt ?

THANK YOU!