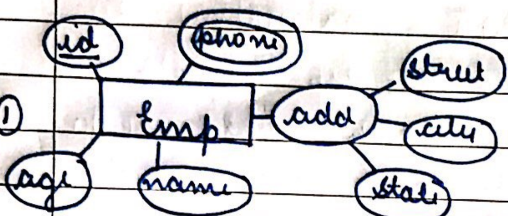
ER to relation

1. mapping Regular entity types
2. mapping weak entity types
3. mapping 1:1 relationship
4. mapping 1:N relationship
5. mapping m:n relationship
6. mapping multivalued and complex attributes
7. mapping class hierarchies.

①


(consider the composition not composite attribute) → (split the composite attribute in the same table.)

employee_details

id	name	age	city	street	state

Emp_phone

id	phone number

(multi-valued new table)

↳ combination (since employee can have multiple phone numbers)

So id + PN → PK (every row individually identifies the entity)

(if PN → office no, mobile no)
↳ (2 emp can have same office no) so PN cannot be a PK

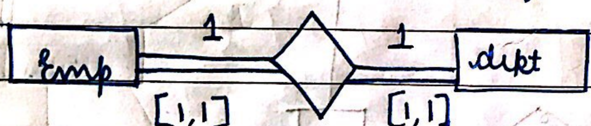
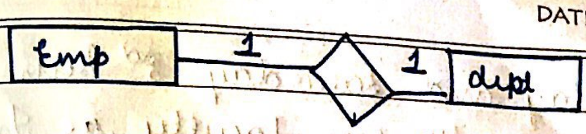
②


table :- should have FK (dept id) in emp table.
or
FK (emp-id) in dept table.

description :- [an employee must work in 1 dept and 1 dep should have 1 employee]

③



apart from having emp and dept table, we will create a 3rd table

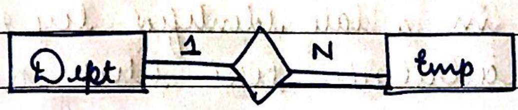
eid	deptid

an employee can atmost work in 1 dept

so can either mak eid or deptid as PK.

description : (an employee can work in 1 dept or there can be employee who do not work in any dept.)

④



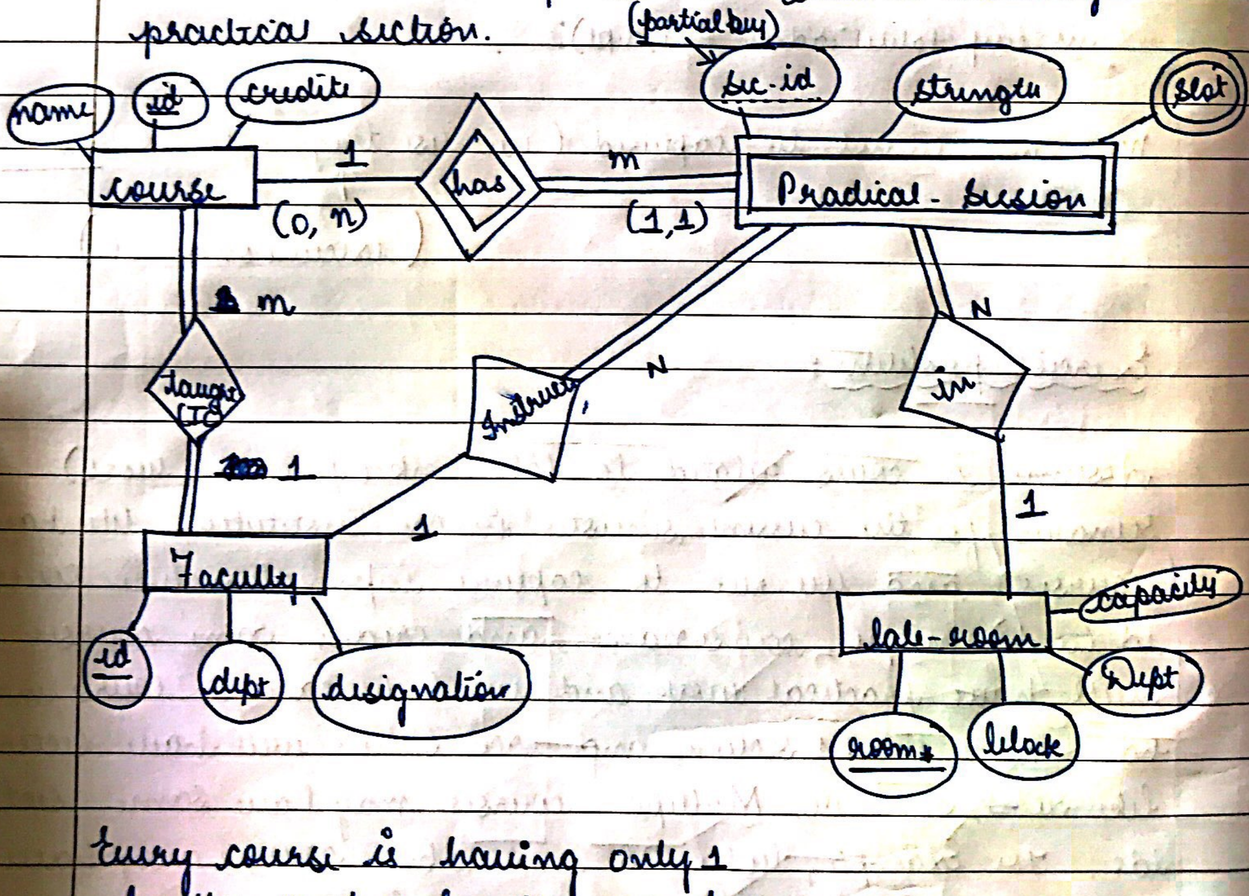
in emp table add PK(dept)

min - max cannot be captured (we use triggers to use min-max)

(executes on event)

Exercise problem :-

Assume a course related to lab work (practical work) scenario for the current semester in an institution. We have courses, and we need to capture information like course id (cid) unique, course name, and credits. Some courses will have practical work and in such cases a course may have more than 1 section, and each section will have section id like sec-1, sec-2 etc. Multiple courses may have same section ids. For Example, both OS and dbms courses may have practical sections. Sec-1 and Sec-2. Each practical section will have strength (no of students), time slots (like Mon 2^{nd} hour) as attributes. One section may be held on more than one slot in a week, for instance OS practical section-2 may be held on monday and saturday 3rd hour. Each course will have exactly one faculty as Instructor co-ordinator; Some faculty may not be instructor co-ordinator for any course. Each faculty is identified by facid, and will have other attributes like name, dept and designation. Each practical section must have one and only one faculty as instructor. IC of a course may be an instructor for one or more of the practical sections of the same course or some other course. Some faculty may not have any practical section allocated. Further, each practical section of a course is conducted in a lab identified by room-number and has other attributes like block, dept, capacity etc. Some labs may not be allocated to any practical section.



Every course is having only 1 faculty and a faculty can teach many courses.

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Course

id	name	credits	F_id

Faculty

id	dept	designation

lab-room

room#	block	dept	capacity

P_session

C_id	sec id	strength	F_id	room#

P session-slot

cid	sec.id	slot

Functional dependency and Normalization.

Functional dependency is a constraint b/w two sets of attributes from the database.

denoted as $X \rightarrow Y$ (Y is functionally dependent on X)

Ex:- $ssn \rightarrow ename$;

$\{ssn, pnumber\} \rightarrow hours$

Note :- FD cannot be inferred. They should be defined by someone who knows the semantics of the database very well.

Department table.

Dname	Dnumber	Mgrssn	Mgrstdate

$Dnumber \rightarrow \{dname, mgrssn, mgrstdate\}$

Essn	Pno	hours

$\{Essn, Pno\} \rightarrow hours$

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Functional dependency : theoretically $\underbrace{\alpha}_{\text{set of attribute.}} \rightarrow \beta$

given value of α we can search the value of β

$f: \alpha \rightarrow \beta$

α	β
a	1
b	2
c	3
a	4

$a \rightarrow 1$

not FD

α	β
a	1
a	2
c	3

multiple occurance of 'a' so, we can not get the exact value of β.

$a \rightarrow$? (Since 2 values)

	$f(x) \rightarrow y$
(✓)	$1 \rightarrow a$
(x)	$1 \rightarrow b$
(✓)	$2 \rightarrow a$

every occurance of '1' we should get a.

Since here for occurance of 1 we are getting a and b. (So its not functionally dependent)

$2 \rightarrow a$ (yes)

value of 'y' can be taken by other value of x.

If there is FD $\alpha \rightarrow \beta$ on a relation it means using α value we can search value of β.

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Formal defination :-

$\alpha \subseteq R, \ \beta \subseteq R$

if there is

FD $\alpha \rightarrow \beta$

if $T_1(\alpha) = t_2[\alpha]$

$\Rightarrow T_1[\beta] = t_2[\beta]$

R

	α	β
t_1	a	b
t_2	a	b

✓

R

α	β
a	b
a	c

✗

for same value of 'α', we cannot have different value of β.

$$\boxed{\begin{array}{ccc} \text{determinant} & & \text{dependent} \\ \alpha & \longrightarrow & \beta \end{array}}$$

$\alpha \longrightarrow \beta$ (FD)

trivial	non-trivial
$AB \rightarrow A$	$\beta \not\subseteq \alpha$
if $\beta \subseteq \alpha$	$AB \rightarrow C$ or
(valid no new thing to be found)	$AB \rightarrow AB\underline{C}$ ↳ something new
Ex:- Calling a call centre, and giving him all required info and that person after checking repeats back the same known info.	Ex:- apart from repeating what's known, he tells something extra.

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Problems :- [1 mark]

R (table name) / Relation

A	B	C	D	E
a	2	3	4	5
2	a	3	4	5
a	2	3	6	5
a	2	3	6	6

a) $A \rightarrow BC$ ✓

b) $DE \rightarrow C$ ✓

c) $C \rightarrow DE$ ✗

d) $BC \rightarrow A$ ✓

[hint1:- if all 'α' values are unique then it is functional dependency holds good.

Irrespective of the value of β]

hint 2:- if 'β' values are same for all FD's then its a hit]

If both hint's do not work, then manually check for values.

'FD' is given by domain expert.

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Inference Rules for FD's.

Armstrong Inference Rules.

Primary rules :-

Rule1 :- Reflexing [RAT rule]

If $x \supseteq y$ ('y' is 'x' subset.) $X \to y$ otherwise non-trivial.

Rule 2 :- Augmentation

$X \to y$ then

$XZ \to YZ$

Rule 3 :- Transitive

$X \to Y$

$Y \to Z$

then $X \to Z$

based on the above 3 rules, we can devise other rules :- Secondary rule.

Rule4 :- Decomposition or projection rule

$X \to YZ$

then

$X \to Y$ &

$X \to Z$

Rule 5 :- Union rule

$X \to A$ then $X \to AB$

$X \to B$

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Rule 6: Psudo transitive

$X \rightarrow Y$
$WY \rightarrow Z$
$WX \rightarrow Z$

how to prove rule 6.

$X \rightarrow Y$ — ①
$WY \rightarrow Z$ — ②

use IR2 (augmentation)

$WX \rightarrow WY$. — ③.

taking ② and ③.

$WY \rightarrow Z$
$WX \rightarrow WY$ using transitive rule.

$WX \rightarrow Z$ (hence derived)

Rule 7:- Composition

$x \rightarrow y$
$z \rightarrow w$
$xz \rightarrow yw$.

We use these axioms to generate closure set.

(Problem type-2)

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Closure on attribute set

Attribute closure of an attribute set 'A' can be defined as a set of attributes which can be functionally determined from it, denoted by F^+.

Example:- ① R(ABC)

$A \rightarrow B$

$B \rightarrow C$.

$(A)^+ = \{A, B, C\}$

② R(ABCDEF)

$A \rightarrow B$

$C \rightarrow DE$

$AC \rightarrow F$

$D \rightarrow AF$

$E \rightarrow CF$

$(D)^+ = \{D, A, F, B\}$

$(DE)^+ = \{D, E, A, F, C, B\}$

③ $R = \{A, B, C, D, E\}$

$A \rightarrow BC$

$CD \rightarrow E$

$B \rightarrow D$

$E \rightarrow A$

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

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

$(B)^+ = \{B, D\}$

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

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④ R(A,B,C,D,E)

$AB \rightarrow C$
$CD \rightarrow E$
$DE \rightarrow B.$

$(AB)^+ = \{A,B,C\}$

$(CD)^+ = \{C,D,E,B\}$

$(DE)^+ = \{D,E,B\}$

⑤ R(A,B,C,D,E,F)

$AB \rightarrow C$
$C \rightarrow A$
$BC \rightarrow D$
$ACD \rightarrow B$
$BE \rightarrow C$
$CE \rightarrow FA$
$CF \rightarrow BD$
$D \rightarrow EF$

$(AB)^+ = \{A,B,C,D,E,F\}$
$(C)^+ = \{C,A\}$
$(BC)^+ = \{B,C,D,E,F,A\}$
$(ACD)^+ = \{A,C,D,B,E,F\}$
$(BE)^+ = \{B,E,C,F,A,D\}$
$(CE)^+ = \{C,E,F,A,B,D\}$
$(CF)^+ = \{C,F,B,D,E,A\}$
$(D)^+ = \{D,E,F\}$

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(6) $R(A,B,C,D,E,F,G)$

$A \rightarrow B$

$BC \rightarrow DE$

$AEG \rightarrow G$

$(AC)^+ = ?$

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

(7) $R(A,B,C,D,E)$

$A \rightarrow BC$

$CD \rightarrow E$

$B \rightarrow D$

$E \rightarrow A$

$(B)^+ = ?$

$(B)^+ = \{B,D\}$

(8) $R(A,B,C,D,E,F)$

$AB \rightarrow C$

$BC \rightarrow AD$

$D \rightarrow E$

$CF \rightarrow B$

$(AB)^+ = ?$

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

(9) $R(A,B,C,D,E,F,G,H)$

$A \rightarrow BC$

$CD \rightarrow E$

$E \rightarrow C$

$D \rightarrow AEH$

$ABH \rightarrow BD$

$DH \rightarrow BC$

$BCD \rightarrow H$?

Ans:- $(BCD)^+ = \{B,C,D,E,A,H\}$

Yes ✓

this dependency is right.

(Problem type-1)

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Problems on Functional dependency. (Gate Quest)

①

X	Y	Z
1	4	2
1	5	3
1	6	3
3	2	2

a) $xy \rightarrow z$ && $z \rightarrow y$ ✗
b) $YZ \rightarrow X$ && $y \rightarrow z$ ✓
c) $YZ \rightarrow X$ && $x \rightarrow z$ ✗
d) $XZ \rightarrow Y$ && $y \rightarrow z$ ✗

②

A	B	C
1	2	4
3	5	4
3	7	2
1	4	2

a) $A \rightarrow B$ && $BC \rightarrow A$ ✗
b) $C \rightarrow B$ && $CA \rightarrow B$ ✗
c) $B \rightarrow C$ && $AB \rightarrow C$ ✓
d) $A \rightarrow C$ && $BC \rightarrow A$. ✗

③ In a schema with attributes A, B, C, D and E following set of FD's are given.

$A \rightarrow B$ $\quad$ $E \rightarrow A$.
$A \rightarrow C$
$CD \rightarrow E$
$B \rightarrow D$

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Which of the following functional dependencies is not implied by the above set?

$CD \rightarrow AC$ ✓

$BC \rightarrow CD$ ✓

$BD \rightarrow CD$ ✗

$AC \rightarrow BC$ ✓

$(\cancel{C}D)^+ = \{\cancel{C}, D, A, \cancel{B}\}$

$(CD)^+ = \{\underline{C}, D, E, \underline{A}\}$

$(BC)^+ = \{B, \underline{C}, \underline{D}\}$

$(BD)^+ = \{B, D\}$

$(AC)^+ = \{A, \underline{C}, \underline{B}, D\}$

(Problem type-3)

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Equivalence of FD

R(A, B, C, D, E, H)

① F: $A \rightarrow C$
$AC \rightarrow D$
$E \rightarrow AD$
$E \rightarrow H$
[$F \subseteq G$]
(f is a subset of G)

G: $A \rightarrow CD$
$E \rightarrow AH$
[$G \subseteq F$]
g is a subset of F.

a) $F \subseteq G$
b) $F \supseteq G$
c) $F = G$ ✓
d) $F \neq G$.

F : compute by taking 'G' FD.
$(A)^+ = \{A, \underline{C}, D\}$
$(AC)^+ = \{A, C, \underline{D}\}$
① $(E)^+ = \{E, A, H\}$
$(E)^+ = \{C, D\}$

G: $(A)^+ = \{A, \underline{C}, \underline{D}\}$

$(E)^+ = \{E, \underline{A}, D, \underline{H}\}$

F and G are functionally equivalent to each other.

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② R(PQRS)

X: $P \rightarrow Q$
$Q \rightarrow R$
$R \rightarrow S$

Y: $P \rightarrow QR$
$R \rightarrow S$.

X: $(P)^+ = \{P, Q, R, S\}$
$(Q)^+ = \{Q\}$ ×
$(R)^+ = \{R, S\}$.

Y: $(P)^+ = \{P, \underline{Q}, \underline{R}, S\}$
$(R)^+ = \{R, S\}$

a) $x \subseteq y$
~~b)~~ $Y \subseteq x$
c) $X = Y$
d) $X \neq Y$

both are not functionally equivalent.
better
'x' has functional dependency.

③ R(A,B,C)

F: $A \rightarrow B$
$B \rightarrow C$
$C \rightarrow A$

G: $A \rightarrow BC$
$B \rightarrow A$
$C \rightarrow A$

F: $(A)^+ = \{A, \underline{B}, C\}$
$(B)^+ = \{B, A, \underline{C}\}$
$(C)^+ = \{C, \underline{A}, B\}$

G: $(A)^+ = \{A, \underline{B}, \underline{C}\}$
$(B)^+ = \{B, C, \underline{A}\}$
$(C)^+ = \{C, \underline{A}, B\}$.

'f' is a subset of G   'g' is a subset of F

both are functionally equivalent.

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④ $R(V, W, X, Y, Z)$

F: $W \to X$
$WX \to Y$
$Z \to WY$
$Z \to V$

G: $W \to XY$
$Z \to WX$

F: $(W)^+ = \{W, \underline{X}, Y\}$
$(WX)^+ = \{W, X, \underline{Y}\}$
$\begin{cases} (Z)^+ = \{Z, \underline{W}, X, \underline{Y}\} \\ (Z)^+ = \end{cases}$

G: $(W)^+ = \{W, \underline{X}, \underline{Y}\}$
$(Z)^+ = \{Z, W, X\}$

F is not a subset of G.

G is not a subset of F

both are functionally not equivalent.

$R(A, C, D, E, H)$

⑤ F: $A \to C$
$AC \to D$
$E \to AD$
$E \to H$

G: $A \to DC$
$E \to A$

F: $(A)^+ = \{A, D, \underline{C}\}$
$(AC)^+ = \{A, C, \underline{D}\}$
$(E)^+ = \{E, \underline{A}, \underline{D}, C\}$

G: $(A)^+ = \{A, \underline{C}, \underline{D}\}$
$(E)^+ = \{E, A, D, H, C\}$

'F' is not a subset of G

'G' is a subset of F

both are not functionally equivalent.

(Problem type-4)

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Irreducible set of FD (canonical form)

Check for redundant attribute and eliminate such attribute.

① $R(W, X, Y, Z)$

$X \rightarrow W$

$WZ \rightarrow XY$

$Y \rightarrow WXZ$

Explanation :-

Redundancy can be

$\alpha \rightarrow \beta$ (considering α & β as set of attributes)

a) Redundancy can be on 'α' side

b) Redundancy can be on β side

c) worst case entire FD is redundant.

we use decomposition (IR)

$\alpha \rightarrow \beta\gamma$

$\alpha \rightarrow \beta$

$\alpha \rightarrow \gamma$.

if $\alpha\beta \rightarrow \gamma$

$\left.\begin{matrix}\alpha \rightarrow \gamma \\ \beta \rightarrow \gamma\end{matrix}\right\} \times$

decomposition cannot be applied on L.H.S ($\times$)

Step 1 :- apply decomposition rule.

$\times$ (Concentrate on RHS)

$X \rightarrow W$ ✓

$WZ \rightarrow X$ ✗

$WZ \rightarrow Y$ ✓

$Y \rightarrow W$ ✗

$Y \rightarrow X$ ✓

$Y \rightarrow Z$ ✓

$(X)^+ = \{X\}$

$(WZ)^+ = \{W, Z, Y, X\}$

$(WZ)^+ = \{W, Z\}$

$(Y)^+ = \{W, Y, X, Z\}$

$(Y)^+ = \{Y, Z\}$

$(Y)^+ = \{Y, W, X\}$

$X \rightarrow W$

$\underline{WZ \rightarrow Y}$ (to check redundancy)

$Y \rightarrow X$

$Y \rightarrow Z$

$(WZ)^+ = \{W, Z, Y, X\}$

$\left.\begin{matrix}(W)^+ = \{W\} \\ (Z)^+ = \{Z\}\end{matrix}\right\}$ both are essential.

✓ [ignoring one of the attributes if we happen to get the same value of closure]

classmate

PAGE

MEGHANA G RAJ
ASSISTANT PROFESSOR

(2) R(A, B, C, D)

$A \to B$
$C \to B$
$D \to ABC$
$AC \to D$

Step 1:- decompose.

$A \to B$ ✓
$C \to B$ ✓
$D \to A$ ✓
$D \to B$ ✗
$D \to C$ ✓
$AC \to D$ ✓

Step 2:- capture closure and eliminate the redundant FD.

$(A)^+ = \{A\}$
$(C)^+ = \{C\}$
$(D)^+ = \{D, B, C\}$
$(D)^+ = \{D, C, B\}$
$(D)^+ = \{D, A, B\}$
$(AC)^+ = \{A, C, B\}$

Finally we have.

$$\left.\begin{array}{l} A \to B \\ C \to B \\ D \to AC \\ AC \to D. \end{array}\right\}$$ minimal cover / canonical cover / Irreducible Set.

$(AC)^+ = \{A, C, D, B\}$ both AC are not redundant.

$$\left.\begin{array}{l} (A)^+ = \{A, B\} \\ (C)^+ = \{C, B\} \end{array}\right\} \times$$

[if $(A)^+$ gives the same ans of $(AC)^+$, then 'C' is redundant]

MEGHANA G RAJ
ASSISTANT PROFESSOR

③ $R(v, w, x, y, z)$

$V \rightarrow W$

$VW \rightarrow X$

$Y \rightarrow VWZ$.

Step1:- decomposition rule.

$V \rightarrow W$ ✓

$VW \rightarrow X$ ✓

$Y \rightarrow V$ ✓

$Y \rightarrow W$ ✗

$Y \rightarrow Z$ ✓

Step 2:-

$(v)^+ = \{v\}$

$(vw)^+ = \{v, w\}$

$(y)^+ = \{y, w, z\}$

$(y)^+ = \{y, v, w, x\}$

$(y)^+ = \{y, v, w, x\}$

Step 3:- $v \rightarrow w$

$vw \rightarrow x$

$y \rightarrow vz$.

$(vw)^+ = \{v, w, x\}$

$(v)^+ = \{v, w, x\}$

$(w)^+ = \{w\}$ ✗ redundant.

$\therefore$ $\left.\begin{array}{l} v \rightarrow wx \\ y \rightarrow vz \end{array}\right\}$ final dependency.

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4(a) $R(A,B,C)$

F:- $A \to BC$
$B \to C$
$A \to B$
$AB \to C$

Step 1 :- decomposition

$A \to B$ ✗
$A \to C$ ✗
$B \to C$ ✓
$A \to B$ ✓
$AB \to C$. ✗

$(A)^+ = \{A, C, B\}$
$(A)^+ = \{A, B, C\}$
$(B)^+ = \{B\}$
$(A)^+ = \{A\}$
$(AB)^+ = \{A, B, C\}$

Step 2 :- $\left.\begin{array}{l} B \to C \\ A \to B \end{array}\right\}$ final functional dependencies.

4(b) $R(A,B,C,D)$

F: $A \to BC$
$B \to C$
$A \to B$
$AB \to C$.

Step 1 :- $A \to B$ ✓
$A \to C$ ✗
$B \to C$
$A \to B$ ✗
$AB \to C$

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$(A)^+ = \{A, B, C\}$

(same as above solved problem)

(5) $R = (A, B, C, D, E)$

F: $A \rightarrow BC$

$CD \rightarrow E$

$B \rightarrow D$

$E \rightarrow A$.

Step 1:- decompose.

$A \rightarrow B$ ✓

$A \rightarrow C$ ✓

$CD \rightarrow E$ ✓

$B \rightarrow D$ ✓

$E \rightarrow A$. ✓

$(A)^+ = \{A, C\}$

$(A)^+ = \{A, B, D\}$

$(CD)^+ = \{C, D\}$

$(B)^+ = \{B\}$

$(E)^+ = \{E\}$

are the given FD's are essential.

(6)

(Problem type - 5)

Keys.

Why do we need keys?

A	B	C
1	a	p
2	b	q
3	c	q
4	c	r

For normalization, keys play an imp part.

Example: [If normalization is a fight, FD is a weapon and keys are the bullets]

What is key?

Ans If we want to extract data from relation, we need keys.

relation → consists of columns and rows.

a) identifying colum (attribute) is easy using the name.

b) but identifying row, is difficult, since rows do not have name.

So, we use attribute name (which is unique) to identify the required records (rows).

above table given 'a' value we can find the values of B and C.

$A \to BC$

$(A)^+ = \{A, B, C\}$

$\boxed{(Key)^+ = R \text{ (entire relation will be obtained)}}$

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Keys = A, BC [can have more than 1 key]

"A key is a set of attributes which can uniquely identify a tuple in a given relation"

Examples :-

① R(A,B,C,D)

A → BC

$(A)^+$ = A,B,C (does not have D)

so not a key.

② R(A,B,C,D)

ABC → D ✓
AB → CD ✓
A → BCD. ✓

} are keys.

Super key :- ABC, AB, A. [ABC, AB]-SK

Candidate key :- (minimal efficient super key) :- A

If a proper subset of a superkey exists, then it cannot be a candidate key.

ABC → D

(subset) AB → CD (by using subset of ABC, we are able to identify the relation, so no need of ABC.

(x)

(by using proper subset of AB, that will 'A' only we are able to get R).

so 'A' is a candidate key.

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'A' is a super key and candidate key.

③ R(A, B, C, D)

B → ACD

ACD → B.

$(B)^+ = \{A, B, C, D\}$ is a SK and CK.

(does not have a proper subset) → $(ACD)^+ = \{A, B, C, D\}$ is a SK and CK (Since there is no proper set.

(AC, AD, CD, A, B, C)

Efficient SK is a CK.

[DBA decides which CK becomes PK)

④ R(A, B, C, D)

AB → C

C → BD

D → A

$(AB)^+ = \{A, B, C, D\}$

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

$(D)^+ = \{D, A\}$

CK = {AB, C}

[Ex:- if we order items online and we have made the payment, but the product has not reached us, when we call customer care they may ask us transaction id, product id which are unique for the order. So, sometimes we may have more than 1 attribute as PK)

super sets

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Finding CK's.

① R (A, B, C, D)

A → B

B → C

C → A

(A, B, C, D)

D → essential attribute.
(which ever combinations we have, we should include 'D').

$(A)^+ = \{A, B, C\}$

$(B)^+ = \{B, C, A\}$

$(C)^+ = \{C, A, B\}$.

none are C.D's

[combi : AD, BD, CD]

$(AD)^+ = \{A, D, B, C\}$ ✓

any other attribute added becomes a super set.

② R (A, B, C, D)

AB → CD

D → A

(A, B, C, D)

B → is a ~~candidate key~~ essential attribute.

Super sets

$(AB)^+ = \{A, B, C, D\}$ ✓

$(DB)^+ = \{D, B, A, C\}$ ✓

$(BC)^+ = \{B, C\}$ X

ABD → can be a super set.

ABC

AB, BD → CK's.

Include B.

A, E, D → try combinations.

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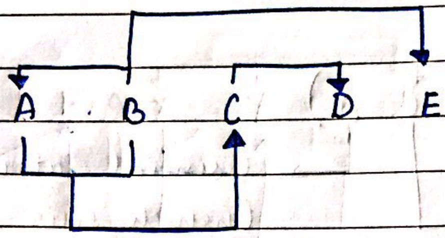
③ $R(A,B,C,D,E,F)$.

$AB \rightarrow C$
$C \rightarrow D$
$B \rightarrow AE$.



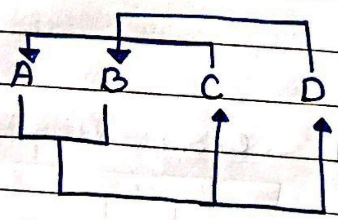
Essential attributes B,F.

$(BF)^+ = \{B,F,A,E,C,D\} \rightarrow CK$.

now since Essential attribute itself becomes CK, no need to check for various combinations.
(BFA) other combi becomes super key.

④ $R(A,B,C,D)$

$AB \rightarrow CD$
$C \rightarrow A$
$D \rightarrow B$.



(Can solve in a diff way)

we do not have any essential attribute, so we need to try different combinations

DATE

$(A)^+ = \{A\}$
$(B)^+ = \{B\}$
$(C)^+ = \{C, A\}$
$(D)^+ = \{D, B\}$.

$(AB)^+ = \{A, B, C, D\}$ ✓
$(AC)^+ = \{A, C\}$ ✗
$(AD)^+ = \{A, D, B, C\}$ ✓
$(BC)^+ = \{B, C, A, D\}$ ✓
$(BD)^+ = \{B, D\}$ ✗
$(CD)^+ = \{C, D, B, A\}$ ✓

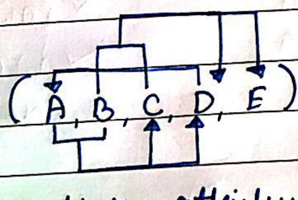
$\{AB, AD, BC, CD\}$ are the candidate keys.

take AC, BD.
ACB = $\{A, C, B, D\}$ ✓
ACD = $\{A, C, D, A\}$ ✓
BDA = $\{B, D, A, C\}$ ✓
BDC - $\{B, D, C, A\}$ ✓

} super keys.

(5) R(A, B, C, D, E)
AB → CD
D → A
BC → DE.

(Can solve in a diff way)



'B' is an essential attribute.
$(AB)^+ = \{A, B, C, D, E\}$ ✓
$(BC)^+ = \{B, C, D, E, A\}$ ✓
$(DB)^+ = \{D, B, A, C, E\}$ ✓
$(BE)^+ = \{B, E\}$ ✗

any other combination will be super key.

ABE, ABC, ABD, BDC → super keys
proper subsets are already CK.

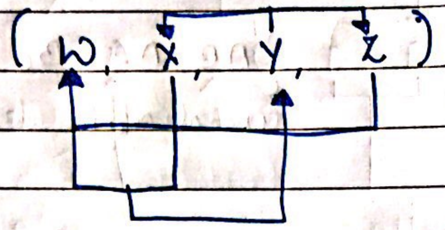
(CK: AB, BC, DB)

⑥ $R(W, X, Y, Z)$

$Z \to W$

$Y \to XZ$

$XW \to Y$



$(W)^+ = WX$

$(X)^+ = XX$

$(Y)^+ = YXZW$ ✓

$(Z)^+ = Z$ ✗

$(WX)^+ = (W, X, Y, Z)$ ✓

$(ZX)^+ = (Z, W, X, Y)$ ✓

$(YX)^+ = (Y, X, Z, W)$ ✓

$(ZY)^+ = (Z, Y, W, X)$ ✓

$(Z, W)^+ = (Z, W)$ ✗

$(Y, W)^+ = (Y, W, X, Z)$ ✓

~~(W, Z)+ = (W, Z)~~

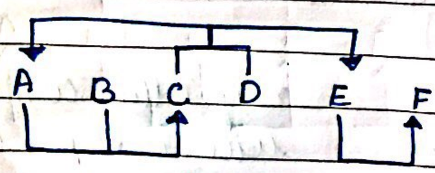
$CK = (WX, ZX, YX, Z, Y, YW)$

⑦ $R(A,B,C,D,E,F)$

$AB \to C$

$DC \to AE$

$E \to F$.



(B,D) – essential keys.

$(BD)^+ = \{B, D\}$ alone cannot determine all attributes.

DATE

ABD, BDC, BDE

$(ABD)^+ = \{A, B, D, C, E, F\}$ ✓
$(BDC)^+ = \{B, D, C, A, E\}$ ✓
$(BDE)^+ = \{B, D, E, F\}$ X

any combination which is already a key then other combi forms SK.

any other combi would lead to super key.

(8) R(A, B, C, D, E)

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

(A, B, C, D, E)

C, E → essential.

$(CE)^+ = \{C, E, A, D, B\}$ ✓ CK.

no need to test for other combi since it would lead to SK.

(9) R(A, B, C, D, E, F, G, H, I, J)

$AB \rightarrow C$
$AD \rightarrow GH$
$BD \rightarrow EF$
$A \rightarrow I$
$H \rightarrow J$.

(A, B, C, D, E, F, G, H, I, J)

essential attribute : (A, B, D)

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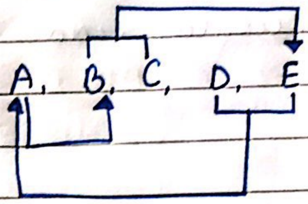
$(ABD)^+ = \{A, B, D, C, I, G, H, E, F, J\}$
└ CK.

DATE

(10) R(A, B, C, D, E)

A → B
BC → E
DE → A



C, D → essential attributes

$(CD)^+ = \{C, D\}$ so try combinations.

ACD, BCD, ECD

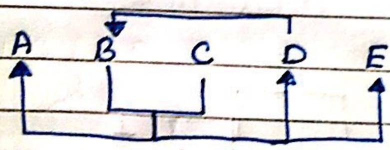
$(ACD)^+ = \{A, C, D, B, E\}$ ✓
$(BCD)^+ = \{B, C, D, E, A\}$ ✓
$(ECD)^+ = \{E, C, D, A, B\}$ ✓

$\}$ CK.

any other combinations becomes SK.

(11) R (A, B, C, D, E)

BC → ADE
D → B



C is essential.

$(AC)^+ = \{A, C\}$ ✗
$(BC)^+ = \{BC, A, D, E\}$

classmate

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ASSISTANT PROFESSOR

$(CD)^+ = \{C, D, B, A, E\}$ ✓ $(CE)^+ = (C, E)$ ✗

BC, CD → CK. $(ACE)^+ = (A, C, E)$ ✗

(12) R(A, B, C, D, E, F)

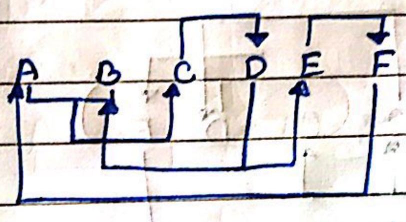
AB → C

C → D

D → BE

E → F

F → A.



$(A)^+ = \{A\}$ ✗

$(B)^+ = \{B\}$ ✗

$(C)^+ = \{C, D, B, E, F, A\}$ ✓

$(D)^+ = \{D, B, E, F, A, C\}$ ✓

$(E)^+ = \{E, F, A\}$ ✗

$(F)^+ = \{F, A\}$ ✗

$(AB)^+ = (A, B, C, D, E, F)$ ✓

$(AE)^+ =$ ✗

$(A,F)^+ =$ ✗

$(B,E)^+ = (B, E, F, A, C, D)$ ✓

$(B,F)^+ = (B, F, A, C, D, E)$ ✓

$(E,F)^+ =$ ✗

$(AEF)^+ = \{A, E, F\}$ ✗

C, D are essential attribute.
any combination would become super key.

(13) R(A, B, C, D, E, F, G, H)

CH → G

A → BC

B → CFH

E → A

F → EG.

'D' is essential attribute.

DATE

$\checkmark$ AD, $\checkmark$ BD, $\times$ CD, $\checkmark$ DE, $\checkmark$ DF, $\times$ DG, $\times$ DH. (15)

CD, DG, DH

$(CDG)^+$ $\times$

$(GDH)^+$ $\times$

$(CDGH)^+ = \times$

CK = AD, BD, DE, DF.

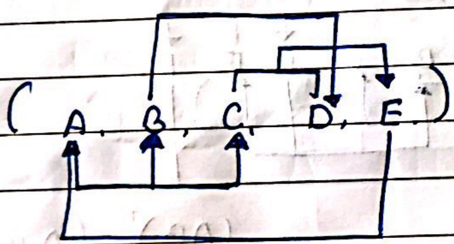
(14) R(A, B, C, D, E)

$A \rightarrow BC$

$CD \rightarrow E$

$B \rightarrow D$

$E \rightarrow A$.



(16)

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

$(B)^+ = \{B, D\}$ $\times$

$(C)^+ = \{C\}$ $\times$

$(D)^+ = \{D\}$ $\times$

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

$(AE)^+ = \{A, E, B, C, D\}$.

$(BC)^+ = \{B, C, D, E, A\}$ $\checkmark$

$(CD)^+ = \{C, D, E, A, B\}$ $\checkmark$

$(BD)^+ = \{B, D\}$ $\times$.

Ck :- A, E, BC, CD.

DATE

(15) R(A,B,C,D,E)

$AB \rightarrow C$
$CD \rightarrow E$
$DE \rightarrow B$.

Is 'AB' a candidat key? if not is 'ABD'?

(A,B, C, D, E)

A D are essential.

$(ABD)^+ = (A,B,C,D,E)$ ✓

(16) R(A,B,C,D,E)

$A \rightarrow BC$ (solved).
$CD \rightarrow E$
$B \rightarrow D$
$E \rightarrow A$.