CSC343H1 Fall 2016 Assignment 3
Part 2: Functional Dependencies, Decompositions, Normal Forms
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Show all of your steps so that we can give part marks where appropriate. There are no marks for simply a correct answer. And you must follow all instructions concerning alphabetical ordering for full marks.

1. Consider a relation schema R with attributes ABCDEFGHIJ with functional dependencies S.

$$S = \{A \rightarrow E,\ BC \rightarrow AE,\ C \rightarrow ACF,\ DE \rightarrow A,\ EFG \rightarrow AB,\ I \rightarrow J,\ J \rightarrow AI\}$$

(a) State which of the given FDs violate BCNF.

They all do.

i)	A → E	A+ = AE, A is not a superkey, A → E violates BCNF
ii)	BC → AE	BC+ = ABCEF, BC is not a superkey, BC → AE violates BCNF
iii)	C → ACF	C+ = ACEF, is not a superkey, C → ACF violates BCNF
iv)	DE → A	DE+ = ADE, is not a superkey, DE → A violates BCNF
v)	EFG → AB	EFG+ = ABEFG, is not a superkey, EFG → AB violates BCNF
vi)	I → J	I+ = AEIJ, is not a superkey, I → J violates BCNF
vii)	J → AI	J+ = AEIJ, is not a superkey, J → AI violates BCNF

(b) Decompose R into BCNF using a lossless-join decomposition into a set of relations in BCNF. You must follow the BCNF decomposition algorithm given in class. Make sure it is clear which relations are in the final decomposition, and don't forget to project the dependencies onto each relation in that final decomposition. Because there are choice points in the algorithm, there may be more than one correct answer. List the final relations in alphabetical order (order the attributes alphabetically within a relation, and order the relations alphabetically).

Decompose R using FD: BC → AE, where BC+ = ABCEF yielding:

R1 = ABCEF
R2 = BCDGHIJ

Project the FDs onto **R1 = ABCEF**

A	**B**	**C**	**E**	**F**	**closure**	**FDs**
✓					A+ = AE	A → E; violates BCNF, abort projection
	✓				B+ = B	nothing
		✓			C+ = ACEF	C → ACF; violates BCNF, abort projection
			✓		E+ = E	nothing
				✓	F+ = F	nothing

Decompose R1 = ABCEF further using FD: A → E, where A+ = AE yielding

R3 = AE
R4 = ABCF

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Project the FDs onto **R3 = AE**

A	E	closure	FDs
✓		A+ = AE	A → E; A is a superkey of R3
	✓	E+ = E	nothing

R3 satisfies BCNF

Project the FDs onto **R4 = ABCF**

A	B	C	F	closure	FDs
✓				A+ = AE	nothing
	✓			B+ = B	nothing
		✓		C+ = ACEF	C → ACF, violates BCNF, abort projection
			✓	F+ = F	nothing
				G+ = G	nothing

Decompose **R4 = ABCF** further using FD: C → ACF, where C+ = ACEF yielding

R5 = BC (satisfies BCNF)
R6 = ACF

Project the FDs onto **R6 = ACF**

A	C	F	closure	FDs
✓			A+ = AE	nothing
	✓		C+ = ACEF	C → ACF, **C is a superkey of R3**
		✓	F+ = F	nothing

R6 satisfies BCNF

Go back and project the FDs onto **R2 = BCDGHIJ**

B	C	D	G	H	I	J	closure	FDs
✓							B+ = B	nothing
	✓						C+ = ACEF	C → ACF; violates BCNF, abort projection
		✓					D+ = D	nothing
			✓				G+ = G	nothing
				✓			H+ = H	nothing
					✓		I+ = AEIJ	I → J; violates BCNF, abort projection
						✓	J+ = AEIJ	J → AI; violates BCNF, abort projection

Decompose R2 = BCDGHIJ further using functional dependency: I → J, yielding:

R7 = IJ
R8 = BCDGHI

Project the FDs onto **R7 = IJ**

I	J	closure	FDs
✓		I+ = AEIJ	I → J; **I is a superkey of R7**
	✓	J+ = AEIJ	J → AI; **J is a superkey of R7**

R7 satisfies BCNF

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Project the FDs onto **R8 = BCDGHI**

B	C	D	G	H	I	closure	FDs
✓						B+ = B	nothing
	✓					C+ = ACEF	nothing
		✓				D+ = D	nothing
			✓			G+ = G	nothing
				✓		H+ = H	nothing, no FD leads to H on RHS
					✓	I+ = AEIJ	Nothing

R8 satisfies BCNF

Final Decomposition

R3 = AE with FD A → E,

~~**R5 = BC** with FD BC → ABCE,~~ but we can discard as this Relation is contained in **R8**

R6 = ACF with FD C → ACF,

R7 = IJ with FD I → J,

R8 = BCDGHI with no FDs

(c) State whether your decomposition is dependency preserving. If not, state which FDs are lost.

No, they are not. Projection of FDs demonstrate that BC → AE, DE → A, and **J → A** from J → AI were lost.

2. Consider a relation P with attributes ABCDEFGH and functional dependencies T .
T = { A → B, BC → ACE, C → B, EF → CG, EFG → ABCD, GH → ABCD **}**

(a) Compute all minimal keys for P

A+ = AB
B+ = B
C+ = BC
D+ = D
E+ = E
F+ = F
G+ = Gs
H+ = H
BC+ = ABCE
EF+ = ABCEFG (no D, H)
EFG+ = ABCDEFG (no H)
GH+ = ABCDEGH (no F)

-F is not on the RHS of any FD, therefore it is part of a key
-H is not on the RHS of any FD, therefore it is part of a key

CFH+ = ABCDEFGH **(is a minimal key)**
EFH+ = ABCDEFGH **(is a minimal key)**
FGH+ = ABCDEFGH **(is a minimal key)**

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(b) Compute a minimal basis for T.

Step 1: Simplify to singleton right-hand sides

1) A → B
2) BC → A
3) BC → C
4) BC → E
5) C → B
6) EF → C
7) EF → G
8) EFG → A
9) EFG → B
10) EFG → C
11) EFG → D
12) GH → A
13) GH → B
14) GH → C
15) GH → D

Step 2: Eliminate redundant FDs

FD	Exclude from T1 when computer closure	Closure	Decision
1) A → B	**1**	A+ = AB, no way to get B without this FD	**keep**
2) BC → A	**2**	BC+ = ABC, no way to get to A without this FD	**keep**
3) BC → C	**3**	C+ = C, so BC → C is redundant	discard
4) BC → E	**3, 4**	BC+ = ABC, no way to get E without this FD	**keep**
5) C → B	**3, 5**	No way to get to B without this FD	**keep**
6) EF → C	**3, 6**	No way to get to C without this FD	**keep**
7) EF → G	**3, 7**	No way to get G without this FD	**keep**
8) EFG → A	**3, 8**	EF+ = ABCEF…	discard
9) EFG → B	**3, 8, 9**	EF+ = ABCEF…	discard
10) EFG → C	**3, 8, 9, 10**	EF+ = ABCEF…	discard
11) EFG → D	**3, 8, 9, 10, 11**	No way to get D without this FD	**keep**
12) GH → A	**3, 8, 9, 10, 11, 12**	GH+ = ABCDGH	discard
13) GH → B	**3, 8, 9, 10, 11, 12, 13**	GH+ = ABCDGH	discard
14) GH → C	**3, 8, 9, 10, 11, 12, 13, 14**	No way to get C without this FD	**keep**
15) GH → D	**3, 8, 9, 10, 11, 12, 13, 15**	No way to get D without this FD	**keep**

Step 3: Reduce the following remaining non-redundant FDs

1) A → B	without this FD, A+ = A, can't reduce the LHS
2) ~~B~~C → A	C+ = BCE, so we can reduce LHS to C
4) ~~B~~C → E	C+ = ABC, so we can reduce LHS to C
5) C → B	
6) EF → C	without this FD, E+ = E, F+ = F, and EF+ = DEFG can't reduce the LHS
7) EF → G	without this FD, E+ = E, F+ = F, and EF+ = ABCEF, can't reduce the LHS
11) EF~~G~~ → D	EF+ = ABCEFG, so we can reduce LHS to EF

14) GH → C	without this FD, G+ = G, H+ = H, and GH+ = DGH, can't reduce the LHS
15) GH → D	without this FD, G+ = G, H+ = H, and GH+ = ABCEGH, can't reduce the LHS

Step 4: Check for redundancies.

FD	Exclude from T1 when computer closure	Closure	Decision
1) A → B	**1**	A+ = A	**keep**
2) C → A	**2**	C+ = BCE	**keep**
3) C → E	**3**	C+ = ABC	**keep**
5) C → B	**5**	C+ = ACE	**keep**
6) EF → C	**6**	EF+ = DEFG	**keep**
7) EF → G	**7**	EF+ = CDEF	**keep**
11) EF → D	**11**	EF+ = CEFG	**keep**
14) GH → C	**14**	GH+ = DGH	**keep**
15) GH → D	**15**	GH+ = ABCEGH	**keep**

The minimal set is:

1) A → B
2) C → A
3) C → E
5) C → B
6) EF → C
7) EF → G
11) EF → D
14) GH → C
15) GH → D

c) Using your minimal basis from the last subquestion, employ the 3NF synthesis algorithm to obtain a lossless and dependency-preserving decomposition of relation R into a collection of relations that are in 3NF.

Step 1: Merge RHS together

A → B
C → ABE
EF → CDG
GH → CD

The set of relations that result:

~~R1(A,B)~~ R2(ABCE) R3(CDEFG) R4(CDGH)

- Since attributes A,B from R1 occur in R2, we can eliminate R1.

R2(ABCE) R3(CDEFG) R4(CDGH)

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- None of the relations have a minimal key, so we add either **CFH, EFH** or **FGH**. The final relation would be:

R2(ABCE) R3(CDEFG) R4(CDGH) **R5(FGH)**

(d) Does your schema allow redundancy? Explain why or why not.

Yes. Without having to complete a full projection of all FDs on the final relations R2, R3, R4, R5, we can easily see that $A \rightarrow B$ or $A+ = AB$ on R2(ABCE) violates BCNF and is not a super key of this relation, therefore could give rise to redundancies.