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Q1.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

(3 Marks) Select, from the choices below, ALL functional dependencies in  $F^+$ .

- A.  $A \rightarrow A$
- B.  $B \rightarrow BC$
- C.  $C \rightarrow DE$
- D.  $D \rightarrow EF$
- E. None of the above

ANSWER: AB

WORKING:

# Method: given  $LHS \rightarrow RHS$ , run Algo 1 with LHS and check if RHS is subset of result

- A.  $A \rightarrow A$  :  $A^+ = ABCDF$  |  $A \rightarrow ABCDF$  (by decomposition:  $A \rightarrow A$ )
- B.  $B \rightarrow BC$ :  $B^+ = ABCDF$  |  $B \rightarrow ABCDF$  (by decomposition:  $B \rightarrow BC$ )
- C.  $C \rightarrow DE$ :  $C^+ = ABCDF$  |  $C \rightarrow ABCDF$  (since it doesn't contain E , it is not in  $F^+$ )
- D.  $D \rightarrow AE$ :  $D^+ = D$  |  $D \rightarrow D$  (since it doesn't contain AE, it is not in  $F^+$ )

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Q2.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

(3 Marks) Select, from the choices below, ALL trivial functional dependencies in  $F^+$ .

- A.  $A \rightarrow A$
- B.  $B \rightarrow BC$
- C.  $C \rightarrow DE$
- D.  $D \rightarrow EF$
- E. None of the above

ANSWER: A

WORKING: from Q1: only AB are in  $F^+$ , then check RHS subset of LHS

- A.  $A \rightarrow A$  : Trivial
- B.  $B \rightarrow BC$ : Non-Trivial
- C.  $C \rightarrow DE$ : Completely Non-Trivial
- D.  $D \rightarrow AE$ : Completely Non-Trivial

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Q3.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

(3 Marks) Select, from the choices below, ALL non-trivial functional dependencies in  $F^+$  that are NOT completely non-trivial.

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- A.  $A \rightarrow A$
- B.  $B \rightarrow BC$
- C.  $C \rightarrow DE$
- D.  $D \rightarrow EF$
- E. None of the above

ANSWER: B

WORKING:

WORKING: from Q1: only AB are in  $F^+$ , then check RHS is NOT subset of LHS  
and check intersection of RHS and LHS is not empty

- A.  $A \rightarrow A$  : Trivial
- B.  $B \rightarrow BC$ : Non-Trivial
- C.  $C \rightarrow DE$ : Completely Non-Trivial
- D.  $D \rightarrow AE$ : Completely Non-Trivial

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Q4.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .  
(3 Marks) Select, from the choices below, ALL completely non-trivial functional dependencies in  $F^+$ .

- A.  $A \rightarrow A$
- B.  $B \rightarrow BC$
- C.  $C \rightarrow DE$
- D.  $D \rightarrow EF$
- E. None of the above

ANSWER: E

WORKING:  $ANS(Q1) - ANS(Q2) - ANS(Q3) \Rightarrow$  if empty then E

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Q5.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .  
(3 Marks) Select, from the choices below, ALL functional dependencies in some minimal cover of  $F$ .

- A.  $A \rightarrow A$
- B.  $B \rightarrow C$
- C.  $C \rightarrow D$
- D.  $D \rightarrow E$
- E. None of the above

ANSWER: B

WORKING:

# Minimal Covers: Run Algo 2 with different possible removal of:  
(1) redundant attributes and

(2)

redundant functional dependencies

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{ A -> B, A -> F, B -> C, C -> A, F -> C, F -> D }
{ A -> F, B -> C, C -> A, C -> B, F -> C, F -> D }
{ A -> B, A -> D, A -> F, B -> C, C -> A, F -> C }
{ A -> D, A -> F, B -> C, C -> A, C -> B, F -> C }
{ A -> B, A -> F, B -> A, C -> A, F -> C, F -> D }
{ A -> B, A -> D, A -> F, B -> A, C -> A, F -> C }
{ A -> D, A -> F, B -> A, C -> B, F -> C }
{ A -> F, B -> A, C -> B, F -> C, F -> D }
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Q6.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

(3 Marks) Select, from the choices below, ALL superkeys of  $R$  with respect to  $F$ .

- A. ABC
- B. BCD
- C. CDE
- D. DEF
- E. None of the above

ANSWER: CD

WORKING: run Algo 1 with each answer and check if attribute closure is  $R$

- A.  $ABC^+ = ABCDF$
- B.  $BCD^+ = ABCDF$
- C.  $CDE^+ = ABCDEF$
- D.  $DEF^+ = ABCDEF$

Q7.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

(3 Marks) Select, from the choices below, ALL keys of  $R$  with respect to  $F$ .

- A. AB
- B. BC
- C. CD
- D. DE
- E. EF

ANSWER: E

WORKING: run Algo 1 with each answer and check if attribute closure is  $R$   
then check if any subset is also superkey

- A.  $AB^+ = ABCDF$
- B.  $BC^+ = ABCDF$
- C.  $CD^+ = ABCDF$
- D.  $DE^+ = DE$
- E.  $EF^+ = ABCDEF$  &  $E^+ = E$  &  $F^+ = ABCDF$

Q8.

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Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

(3 Marks) Select, from the choices below, ALL prime attributes of  $R$  with respect to  $F$ .

- A. A
- B. B
- C. C
- D. D
- E. E
- F. F

ANSWER: ABCEF

WORKING: run Algo 1 from smallest possible set in powerset of  $R$   
there's no need to compute any set that is superset of known key  
e.g., if  $AE$  is key, there's no need to compute

$ABE^+$

# Keys:  $\{AE, EF, BE, CE\}$   
# Prime Attributes: ABCEF

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Q9.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

(3 Marks) Given a decomposition of  $R$ :

$R_1(A,E)$

$R_2(A,B,C,D,F)$

Select, from the choices below, ALL true statements.

- A. The decomposition is a lossless-join BCNF decomposition of  $R$
- B. The functional dependency  $A \rightarrow D$  is in  $F^+$  and not preserved by the decomposition
- C. The functional dependency  $CF \rightarrow D$  is in  $F^+$  and not preserved by the decomposition
- D. The functional dependency  $AB \rightarrow D$  is in  $F_{R_2}$
- E. None of the above

ANSWER: AD

WORKING:

A. Method 1: by BCNF Decomposition

$A \rightarrow BCDF$  violates BCNF of  $R$ :  $R_1(ABCF)$  &  $R_2(AE)$  [ with renaming ]

Method 2: by Corollary 1 it is lossless-join decomposition (i.e., check

Corollary 1)

since  $A^+ = ABCFD$  so  $A \rightarrow R_2$  (and  $R_1 \cap R_2 = A$ )

by Algo 5  $R_1$  and  $R_2$  does not violate BCNF

B. by Algo 4: it is actually a dependency-preserving decomposition

C. by Algo 4: it is actually a dependency-preserving decomposition

D. by Algo 3:  $AB \rightarrow ABCDF$  since  $AB^+$  w.r.t.  $F_{R_2} = ABCDF$

E. None of the above

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Q10.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

Questions 10-12 also use the following proof that the set of attributes  $\{ E, F \}$  is a superkey of  $R$  with respect to  $F$ . The proof uses Extended Armstrong's Axiom such that ALL the rules in Extended Armstrong's Axiom are utilized.

- (1)  $F \rightarrow CD$  [ Given ]
- (2)  $C \rightarrow AB$  [ Given ]
- (3)  $EF \rightarrow ECD$  [ \_Q11\_ ]
- (4) \_\_\_\_\_ [ Decomposition of (3) ]
- (5)  $EF \rightarrow AB$  [ Transitivity of (4) and (2) ]
- (6) \_\_\_\_\_ [ \_Q11\_ ]
- (7)  $EF \rightarrow ABCDEF$  [ Union of ( \_Q12\_, \_Q12\_, ..., \_Q12\_ ) ]

You are advised to fill the blanks in the proof before attempting the questions.

(2 Marks) Select, from the choices below, ALL functional dependencies used in the proof that can be put in place of the blanks \_Q10\_.

- A.  $EF \rightarrow A$
- B.  $EF \rightarrow B$
- C.  $EF \rightarrow C$
- D.  $EF \rightarrow D$
- E.  $EF \rightarrow E$
- F.  $EF \rightarrow F$
- G. None of the above

ANSWER: CF

WORKING: Combined working Q10-Q12

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Q11.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

Questions 10-12 also use the following proof that the set of attributes  $\{ E, F \}$  is a superkey of  $R$  with respect to  $F$ . The proof uses Extended Armstrong's Axiom such that ALL the rules in Extended Armstrong's Axiom are utilized.

- (1)  $F \rightarrow CD$  [ Given ]
- (2)  $C \rightarrow AB$  [ Given ]
- (3)  $EF \rightarrow ECD$  [ \_Q11\_ ]
- (4) \_\_\_\_\_ [ Decomposition of (3) ]
- (5)  $EF \rightarrow AB$  [ Transitivity of (4) and (2) ]
- (6) \_\_\_\_\_ [ \_Q11\_ ]
- (7)  $EF \rightarrow ABCDEF$  [ Union of ( \_Q12\_, \_Q12\_, ..., \_Q12\_ ) ]

You are advised to fill the blanks in the proof before attempting the questions.

(2 Marks) Select, from the choices below, ALL rules used in the proof that can be put in place of the blanks \_\_Q11\_\_.

- A. Reflexivity
- B. Augmentation of (1) with F
- C. Augmentation of (1) with E
- D. Augmentation of (2) with F
- E. Augmentation of (2) with E
- F. Augmentation of (2) with D
- G. None of the above

ANSWER: AC

WORKING: Combined working Q10-Q12

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Q12.

Questions 1-14 use the schema  $R(A,B,C,D,E,F)$  and set of functional dependencies  $F = \{ A \rightarrow D, C \rightarrow AB, B \rightarrow AC, B \rightarrow AC, A \rightarrow BF, F \rightarrow CD \}$ .

Questions 10-12 also use the following proof that the set of attributes  $\{ E, F \}$  is a superkey of  $R$  with respect to  $F$ . The proof uses Extended Armstrong's Axiom such that ALL the rules in Extended Armstrong's Axiom are utilized.

- (1)  $F \rightarrow CD$  [ Given ]
- (2)  $C \rightarrow AB$  [ Given ]
- (3)  $EF \rightarrow ECD$  [ \_\_Q11\_\_ ]
- (4) \_\_\_\_Q10\_\_\_\_ [ Decomposition of (3) ]
- (5)  $EF \rightarrow AB$  [ Transitivity of (4) and (2) ]
- (6) \_\_\_\_Q10\_\_\_\_ [ \_\_Q11\_\_ ]
- (7)  $EF \rightarrow ABCDEF$  [ Union of ( \_\_Q12\_\_, \_\_Q12\_\_, ..., \_\_Q12\_\_ ) ]

You are advised to fill the blanks in the proof before attempting the questions.

(1 Marks) Select, from the choices below, ALL line numbers that can be put in place of the blanks \_\_Q12\_\_. Select the MINIMAL number of combinations.

- A. (1)
- B. (2)
- C. (3)
- D. (4)
- E. (5)
- F. (6)

ANSWER: CEF

WORKING: Combined working Q10-Q12

Proof:

- (1)  $F \rightarrow CD$  [ Given ]
- (2)  $C \rightarrow AB$  [ Given ]

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- (3) EF → ECD [ Augmentation of (1) with E ]
- (4) EF → C [ Decomposition of (3) ]
- (5) EF → AB [ Transitivity of (4) and (2) ]
- (6) EF → F [ Reflexivity ]
- (7) EF → ABCDEF [ Union of (3,5,6) ]

NOTE: for Q12, Union of (3,4,5,6) is also possible but (4) is unnecessary

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Q13.

Questions 1-14 use the schema R(A,B,C,D,E,F) and set of functional dependencies F = { A → D, C → AB, B → AC, A → BF, F → CD }.

(5 marks) Give one possible minimal cover of F.

If a functional dependency AB → CD is in your answer, then you should write AB → CD

- You should use dash (-) and greater than symbol (>) instead of arrow to form the arrow (→) with a space before and after
- There should be NO space or other symbols between attributes
- The attributes on each LHS and RHS should be arranged in ascending order
- The attributes should be in uppercase
- The attributes should NOT be enclosed in bracket

If you have multiple functional dependencies such as A → B and C → D in your answer, you should write A → B; C → D where each functional dependency follows the above mentioned requirement

- The functional dependency must be separated by a semi-colon (;)
- There should be a space between the functional dependencies after the semi-colon

ANSWER:

# Using Algo 2: { A → F, B → C, C → A, C → B, F → C, F → D }

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Q13.

Questions 1-14 use the schema R(A,B,C,D,E,F) and set of functional dependencies F = { A → D, C → AB, B → AC, A → BF, F → CD }.

(5 marks) Using the minimal cover computed from Q13, give one possible lossless-join, dependency-preserving, 3NF decomposition of R with respect to F.

If R1 is a relation in your answer for the decomposition with attributes { B, C, D }, then you should write R1(BCD)

- There should be NO space or other symbols between attributes
- The attributes should be arranged in ascending order
- The attributes should be in uppercase
- The attributes should be enclosed in bracket

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- The name of the relation should be before the bracket, without space

If you have multiple relations such as R1 and R2 in your answer, you should write R1(...); R2(...) where ... is the set of attributes for each relation following the above mentioned requirement

- The relations must be separated by a semi-colon (;)
- There should be a space between the relations after the semi-colon'

ANSWER:

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# Key = { BE, CE, EF, AE }
# From Q13 { A -> F, B -> C, C -> A, C -> B, F -> C, F -> D }
# - Union { A -> F, B -> C, C -> AB          , F -> CD          }
# R1(AF), R2(BC), R3(ABC), R4(CDF)
# Possibilities:
# (1) R1(AF), R2(BC), R3(ABC), R4(CDF), RK(BE)
# (2) R1(AF), R2(BC), R3(ABC), R4(CDF), RK(CE)
# (3) R1(AF), R2(BC), R3(ABC), R4(CDF), RK(EF)
# (4) R1(AF), R2(BC), R3(ABC), R4(CDF), RK(AE)
# Remove Redundancies:
# (1) R1(AF), R3(ABC), R4(CDF), RK(BE)
# (2) R1(AF), R3(ABC), R4(CDF), RK(CE)
# (3) R1(AF), R3(ABC), R4(CDF), RK(EF)
# (4) R1(AF), R3(ABC), R4(CDF), RK(AE)
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