Exercise 3: Solution
Normalization

DBS

- Multiple correct solutions are possible.
- The model solutions provide only one correct solution/ direction (along with some assumptions → identify those assumptions).
- You must write your additional assumptions together with your solution.
- Discuss your alternative solutions and assumptions with the TA.

Question 1

- Key: AD
- By first decomposing on $B \rightarrow C$, we first get $R1(B, C)$ and $R2(A, B, D)$.
- $R2$ is not in BCNF, so we must decompose further: R3(A,D) and R4(B, D).

Question 1

- Second choice:
- By first decomposing on $D \rightarrow B$, we first get $R1(B, C, D)$ and $R2(A, D)$.
- $R1$ is not in BCNF, so we must decompose further.
- In both cases, we end up with three relations, $Ra(A, D)$, $Rb(B, C)$ and $Rc(B, D)$.

Question 2

- Case 1: There are no nontrivial FDs. AB is key; so we have AB$\rightarrow$AB, which trivial. (only nontrivial FDs can violate BCNF)
- Case 2: A$\rightarrow$B holds, but B$\rightarrow$A does not. A is the key. The only nontrivial FD is A$\rightarrow$B; no BCNF violation.
- Case 3: B$\rightarrow$A holds, but A$\rightarrow$B does not. A is the key. The only nontrivial FD is B$\rightarrow$A; no BCNF violation.
- Case 4: Both A$\rightarrow$B and B$\rightarrow$A hold. A and B are both keys; no BCNF violation.

Question 3(a)

- The usual procedure to find the keys is to take the closure of all 63 nonempty subsets.
- However, if we notice that none of the right sides of the FDs contains attributes H and S.
- Thus we know that attributes H and S must be part of any key.
- We eventually will find out that **HS** is the only key for the Courses relation.

Question 3(b)

- Check if any of the FDs can be removed.
- If we remove any one of the five FDs, the remaining four FDs do not imply the removed FD.
- Check if any of the LHS attribute of an FD can be removed without losing the dependencies.
- This is not the case for the four FDs that contain two attributes on the left side.
- Thus, the given set of FDs is a minimal basis.

Question 3(c)

- Since the only key is HS, the given set of FDs has some dependencies that violate 3NF.
- We also know that the given set of FDs is a minimal basis.
- Thus the decomposed relations are CT, HRC, HTR, HSR and CSG.
- Since the relation HSR contains a key, we do not need to add an additional relation.
- The final set of decomposed relations is CT, HRC, HTR, HSR and CSG.

Question 4

- G ={Z→W, Y→X, Y→Z, XW→Y}, where G is a minimal basis
- Use closure method to find keys
- Possible keys: Y, WX, XZ
- Decomposed relations: R1(Z, W), R2(X, Y, Z), R3(X, Y, W)
- Then all LHS of FDs are superkeys; therefore relations are in BCNF

Question 5(a)

- FDs: $A \rightarrow BC$, $E \rightarrow A$, $CD \rightarrow E$, $B \rightarrow D$
- Keys? A? E? CD?
- (a) Decomposition: R1(A,B,C) and R2(A,D,E)
- (b) Decomposition: R3(A,B,C,D) and R4(C,D,E)
- Is decomposition lossless (can be joined back)?
- Is decomposition dependency preserving (no FDs lost)?
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Question 5(a)

- Decomposition is lossless since
  - The two tables have a common attribute A, and
  - A is a superkey for R1(A,B,C)
- FDs that hold on R1(A,B,C)
  - $A \rightarrow BC$ since R1 contains A, B, and C
- FDs that hold on R2(A,D,E)
  - $E \rightarrow A$, since R2 contains A and E
- Two other FDs need to be checked: $CD \rightarrow E$, $B \rightarrow D$
  - Given $A \rightarrow BC$ and $E \rightarrow A$, we have:
  - $\{B\}^+ = \{B\}$, so $B \rightarrow D$ is not preserved
  - $\{CD\}^+ = \{CD\}$, so $CD \rightarrow E$ is not preserved
- Decomposition is NOT dependency-preserving

Question 5(b)

- Decomposition is lossless since
  - The two tables have common attributes CD, and
  - CD is a superkey for R4(C,D,E)
- FDs that hold on R3(A,B,C,D)
  - $A \rightarrow BC$, $CD \rightarrow A$, and $B \rightarrow D$ since R1 contains A, B, C, and D
- FDs that hold on R4(C,D,E)
  - $CD \rightarrow E$, $E \rightarrow CD$
- One other FDs needs to be checked: $E \rightarrow A$
  - Given $A \rightarrow BC$, $CD \rightarrow A$, $CD \rightarrow E$, $E \rightarrow CD$ and $B \rightarrow D$, we have:
  - $\{E\}^+ = \{E, C, D, A, B\}$, so $E \rightarrow A$ is preserved
- Decomposition is dependency-preserving

Question 6

- No.
- Unless A → B or A → C is satisfied in R, R1 join R2 may generate entries that do not belong to R.

R

A	B	C
1	2	3
1	4	5

→

R1

A	B
1	2
1	4

R2

A	C
1	3
1	5

→

$R1 \bowtie R2$

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