

## Exercise 19.7 from the TextBook

Work through the following example without referring to the answers below. Once you have completed them, compare your answers to those from the textbook.

**Exercise 19.7** Suppose you are given a relation  $R$  with four attributes  $ABCD$ . For each of the following sets of FDs, assuming those are the only dependencies that hold for  $R$ , do the following: (a) Identify the candidate key(s) for  $R$ . (b) Identify the best normal form that  $R$  satisfies (1NF, 2NF, 3NF, or BCNF). (c) If  $R$  is not in BCNF, decompose it into a set of BCNF relations that preserve the dependencies.

1.  $C \rightarrow D, C \rightarrow A, B \rightarrow C$
2.  $B \rightarrow C, D \rightarrow A$
3.  $ABC \rightarrow D, D \rightarrow A$
4.  $A \rightarrow B, BC \rightarrow D, A \rightarrow C$
5.  $AB \rightarrow C, AB \rightarrow D, C \rightarrow A, D \rightarrow B$

**Answer 19.7**

1. (a) Candidate keys:  $B$   
(b)  $R$  is in 2NF but not 3NF.  
(c)  $C \rightarrow D$  and  $C \rightarrow A$  both cause violations of BCNF. One way to obtain a (lossless) join preserving decomposition is to decompose  $R$  into  $AC$ ,  $BC$ , and  $CD$ .
  
2. (a) Candidate keys:  $BD$   
(b)  $R$  is in 1NF but not 2NF.  
(c) Both  $B \rightarrow C$  and  $D \rightarrow A$  cause BCNF violations. The decomposition:  $AD$ ,  $BC$ ,  $BD$  (obtained by first decomposing to  $AD$ ,  $BCD$ ) is BCNF and lossless and join-preserving.
  
3. (a) Candidate keys:  $ABC$ ,  $BCD$   
(b)  $R$  is in 3NF but not BCNF.  
(c)  $ABCD$  is not in BCNF since  $D \rightarrow A$  and  $D$  is not a key. However if we split up  $R$  as  $AD$ ,  $BCD$  we cannot preserve the dependency  $ABC \rightarrow D$ . So there is no BCNF decomposition.
  
4. (a) Candidate keys:  $A$   
(b)  $R$  is in 2NF but not 3NF (because of the FD:  $BC \rightarrow D$ ).  
(c)  $BC \rightarrow D$  violates BCNF since  $BC$  does not contain a key. So we split up  $R$  as in:  $BCD$ ,  $ABC$ .
  
5. (a) Candidate keys:  $AB$ ,  $BC$ ,  $CD$ ,  $AD$   
(b)  $R$  is in 3NF but not BCNF (because of the FD:  $C \rightarrow A$ ).  
(c)  $C \rightarrow A$  and  $D \rightarrow B$  both cause violations. So decompose into:  $AC$ ,  $BCD$  but this does not preserve  $AB \rightarrow C$  and  $AB \rightarrow D$ , and  $BCD$  is still not BCNF because  $D \rightarrow B$ . So we need to decompose further into:  $AC$ ,  $BD$ ,  $CD$ . However, when we attempt to revive the lost functional dependencies by adding  $ABC$  and  $ABD$ , we find that these relations are not in BCNF form. Therefore, there is no BCNF decomposition.