Lossless Join Decomposition - 3NF
Solutions

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1. Are these schemas in 3NF?
2. Decompose the relations, as necessary, into collections of relations that are in 3NF.

   (a) $R = \{city, street, zip\}$
   $\mathcal{F} = \{city, street \rightarrow zip,\ zip \rightarrow city\}$

   $\{city, street\}$ and $\{zip, street\}$ are the only keys. The left hand side of $city, street \rightarrow zip$ is a key, so it's ok. The right hand side of $zip \rightarrow city$ is part of a key, so it's ok. Therefore the schema is in 3NF.

   (b) $R = ABC$
   $\mathcal{F} = \{A \rightarrow B, B \rightarrow C\}$

   The only key is A. The lhs of $B \rightarrow C$ is not a superkey, the rhs is not part of a key. Therefore the schema is not in 3NF.

   We decompose R into $R_1 = AB$ and $R_2 = BC$.

   (c) $R = ABCD$
   $\mathcal{F} = \{AB \rightarrow C,\ C \rightarrow D,\ D \rightarrow A\}$

   The keys are AB, BC and BD. The lhs of $AB \rightarrow C$ is a key, the rhs of $C \rightarrow D$ is part of a key, the rhs of $D \rightarrow A$ is part of a key. Therefore the schema is in 3NF.

   (d) $R = ABCD$
   $\mathcal{F} = \{B \rightarrow C,\ B \rightarrow D\}$

   The only key is AB. The lhs of $B \rightarrow C$ is not a superkey, the rhs is not part of a key. Therefore the schema is not in 3NF.

We decompose R into $R_1 = BC$ and $R_2 = BD$. The key AB isn't contained in any schema so we add $R_3 = AB$. We can replace R_1 and R_2 by $R_4 = BCD$. The decomposition is then $\rho = \{BCD, AB\}$.

(e) $R = ABCD$
$\mathcal{F} = \{AB \to C,\ BC \to D,\ CD \to A,\ AD \to B\}$

The only keys are $\{AB, BC, CD, AD\}$. All the functional dependencies have their lhs as keys. Therefore the schema is in 3NF.