Question 1:

$R(A, B, C, D, E, G, H, I, J)$, $F$ = {EC → B, C → D, G → BH, H → ACD, E → GHI, IJ → EG}

Q(1): All the candidate keys, Prime and non-prime attributes

A(1): There are two candidate keys for R: $\{I,\ J\},\ \{E,\ J\}$

Prime attributes: $E,\ I,\ J$

Non-prime attribute: $A,\ B,\ C,\ D,\ G,\ H$

Q(2): Total number of super keys, List 5 of them.

A(2): There are two candidate keys: $\{I,\ J\},\ \{E,\ J\}$, And there are six non-prime attributes.

To construct a super key, we need to select one or two keys from the candiadte keys and also need to select equal or large than zero non-prime attributes.

So the total number of super key is:

$$\left(C_2^1 + C_2^2\right) * \left(C_6^0 + C_6^1 + C_6^2 + C_6^3 + C_6^4 + C_6^5 + C_6^6\right)$$

the result is 192

List 5 of them: $\{A, I,\ J\}, \{B,\ I,\ J\}, \{C,\ I,\ J\}, \{D,\ I,\ J\}, \{G, I,\ J\}$

Q(3): Highest normal form of $R$

A(3): The highest normal form of R is 1NF

Proof:

1: A Relational Database Management System does not enable multi-valued or composite attribute. So,
the relation R is in 1st normal form.

2: Because E → GHI and according to the projectivity of armstrong's axioms. We can get E → G. So G is partially functionally dependent on the candidate key $\{E,\ J\}$

Q(4): minimal cover $F_m$ for $F$

A(4):

step1: break right side into individual attributes:

{EC → B, C → D, G → H, G → B, H → A, H → C, H → D, E → G, E → H, E → I, IJ → E, IJ →G}

step2: for $EC\ \rightarrow\ B, in\ F - \left\{EC\ \rightarrow\ B\right\}$, $B$ is in $\{E, C\}^+ = \{A,\ B,\ C,\ D,\ E,\ G, H, I\}$, delete

for $C\ \rightarrow\ D, in\ F - \left\{C\ \rightarrow\ D\right\}$, $D$ is not in $\{C\}^+ = \{C\}$, reserve

for $G\ \rightarrow\ B, in\ F - \left\{G\ \rightarrow\ B\right\}$, $B$ is not in $\{G\}^+ = \{G,\ H,\ A,\ C,\ D\}$, reserve

for $G\ \rightarrow\ H, in\ F - \left\{G\ \rightarrow\ H\right\}$, $H$ is not in $\{G\}^+ = \{G,\ B\}$, reserve for $H \rightarrow A, in\ F - \left\{H \rightarrow A\right\}$, $A$ is not in $\{H\}^+ = \{H, C, D\}$, reserve

for $H \rightarrow C, in\ F - \left\{H \rightarrow C\right\}$, $C$ is not in $\{H\}^+ = \{H, A, D\}$, reserve

for $H \rightarrow D, in\ F - \left\{H \rightarrow D\right\}$, $D$ is in $\{H\}^+ = \{H, A, C, D\}$, delete

for $E \rightarrow G, in\ F - \left\{E \rightarrow G\right\}$, $G$ is not in $\{E\}^+ = \{E, H, I, A, C, D, B\}$, reserve

for $E \rightarrow H, in\ F - \left\{E \rightarrow H\right\}$, $H$ is in $\{E\}^+ = \{E, G, I, B, H, A, C, D\}$, delete

for $E \rightarrow I, in\ F - \left\{E \rightarrow I\right\}$, $I$ is not in $\{E\}^+ = \{E, G, H, B, A, C, D\}$, reserve

for $IJ \rightarrow E, in\ F - \left\{IJ \rightarrow E\right\}$, $E$ is not in $\{IJ\}^+ = \{I, J, G, B, H, A, C, D\}$, reserve

for $IJ \rightarrow G, in\ F - \left\{IJ \rightarrow G\right\}$, $G$ is in $\{IJ\}^+ = \{I, J, E, G, H, B, A, C, D\}$, delete

step3:

For $IJ \rightarrow E$, it can not be divided again.

The final result is $\left\{C \rightarrow D,\ G \rightarrow B,\ G \rightarrow H,\ H \rightarrow A,\ H \rightarrow C,\ E \rightarrow G, E \rightarrow I,\ IJ \rightarrow E\right\}$

Q(5): If the the decomposition is dependency-preserving?

A(5): It is NOT dependency-preserving

$R_1 = \{A, B, E\},\ F_1 = \{\Phi\}$

$R_2 = \{C, D, H\},\ F_2 = \left\{C \rightarrow D\right\}$

$R_3 = \{E, G, H, I, J\}, F_3 = \left\{E \rightarrow GHI, IJ \rightarrow EG\right\}$

we verify that $G \rightarrow BH$ can not be inferred by $F_1 \cup F_2 \cup F_3$.

$\{G\}^+|_{F_1 \cup F_2 \cup F_3} = \{G\}$, so it is not dependency-preserving

Q(6): If the decomposition satisfies the lossless join property?

A(6): It satisfies the lossless join property

Initially S is

| | $A$ | $B$ | $C$ | $D$ | $E$ | $G$ | $H$ | $I$ | $J$ |
|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | a | a | b | b | a | b | b | b | b |
| $R_2$ | b | b | a | a | b | b | a | b | b |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $R_3$ | b | b | b | b | a | a | a | a | a |

$R_1$ *and* $R_3$ *share the same* $E$. Take the $E \rightarrow GHI$

| | $A$ | $B$ | $C$ | $D$ | $E$ | $G$ | $H$ | $I$ | $J$ |
|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | a | a | b | b | a | a | a | a | b |
| $R_2$ | b | b | a | a | b | b | a | b | b |
| $R_3$ | b | b | b | b | a | a | a | a | a |

$R_1$, $R_2$ *and* $R_3$ *share the same* $H$. Take the $H \rightarrow ACD$

| | $A$ | $B$ | $C$ | $D$ | $E$ | $G$ | $H$ | $I$ | $J$ |
|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | a | a | b | a | a | a | a | a | b |
| $R_2$ | a | b | a | a | b | b | a | b | b |
| $R_3$ | a | b | a | a | a | a | a | a | a |

$R_1$ *and* $R_3$ *share the same* $G$. Take the $G \rightarrow BH$

| | $A$ | $B$ | $C$ | $D$ | $E$ | $G$ | $H$ | $I$ | $J$ |
|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | a | a | b | a | a | a | a | a | b |
| $R_2$ | a | b | a | a | b | b | a | b | b |
| $R_3$ | a | a | a | a | a | a | a | a | a |

The row of $R_3$ is all a. So it is lossless

Q(7): step-by-step lossless decomposition of R into BCNF

A(7): Answer is not unique

$R(A, B, C, D, E, G, H, I, J)$, $F = $ {EC → B, C → D, G → BH, H → ACD, E → GHI, IJ → EG}

candidate key= $\{I,\ J\}$, $\{E,\ J\}$

step 1: For FD $C \rightarrow D$ , $C$ is not a super key, violating BCNF.

decompose

$\{C\}^+ = \{C, D\}$
$R_1 = \{C, D\},\ key = \{C\}$
$R_2 = \{A, B, C, E, G, H, I, J\},\ key = \{E, J\}, \{I, J\}$

step 2: Check $R_1$ for BCNF condition, it is OK

step 3: Check $R_2$ for BCNF condition
$G \rightarrow BH$ is not a super key, violating BCNF
$\{G\}^+ = \{G, B, H, A, C\}$
$R_{21} = \{G, B, H, A, C\},\ key = \{G\}$
$R_{22} = \{G, E, I, J\},\ key = \{E, J\}, \{I, J\}$

step 4: Check $R_{21}$ for BCNF condition:
$H \rightarrow ACD$ is not a super key, violating BCNF
decompose
$\{H\}^+ = \{A, C\}$
$R_{211} = \{H, A, C\},\ key = \{H\}$
$R_{212} = \{G, B, H\},\ key = \{G\}$

step 5: check $R_{211}$ for BCNF condition, it is OK

step 6: check $R_{212}$ for BCNF condition, it is OK

step 7: check $R_{22}$ for BCNF condition
$E \rightarrow GHI$ is not a super key, violating BCNF
decompose
$\{E\}^+ = \{G, I\}$
$R_{221} = \{E, G, I\},\ key = \{E\}$
$R_{222} = \{E, J\},\ key = \{E, J\}$

step 8: check $R_{221}$ for BCNF condition, it is OK

step 9: check $R_{222}$ for BCNF condition, it is OK

step 10: Check if it is a lossless decomposition

| | $A$ | $B$ | $C$ | $D$ | $E$ | $G$ | $H$ | $I$ | $J$ |
|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | | | a | a | | | | | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $R_{211}$ | a | | a | | | | a | | |
| $R_{212}$ | | a | | | | a | a | | |
| $R_{221}$ | | | | | a | a | | a | |
| $R_{222}$ | | | | | a | | | | a |

$R_{222}$ and $R_{221}$ share the same $E \longrightarrow GHI$

| | $A$ | $B$ | $C$ | $D$ | $E$ | $G$ | $H$ | $I$ | $J$ |
|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | | | a | a | | | | | |
| $R_{211}$ | a | | a | | | | a | | |
| $R_{212}$ | | a | | | | a | a | | |
| $R_{221}$ | | | | | a | a | | a | |
| $R_{222}$ | | | | | a | a | | a | a |

$R_{222}$ and $R_{212}$ share the same $G \longrightarrow BH$

| | $A$ | $B$ | $C$ | $D$ | $E$ | $G$ | $H$ | $I$ | $J$ |
|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | | | a | a | | | | | |
| $R_{211}$ | a | | a | | | | a | | |
| $R_{212}$ | | a | | | | a | a | | |
| $R_{221}$ | | | | | a | a | | a | |
| $R_{222}$ | | a | | | a | a | a | a | a |

$R_{222}$ and $R_{211}$ share the same $H \longrightarrow ACD$

| | $A$ | $B$ | $C$ | $D$ | $E$ | $G$ | $H$ | $I$ | $J$ |
|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | | | a | a | | | | | |
| $R_{211}$ | a | | a | | | | a | | |
| $R_{212}$ | | a | | | | a | a | | |
| $R_{221}$ | | | | | a | a | | a | |
| $R_{222}$ | a | a | a | | a | a | a | a | a |

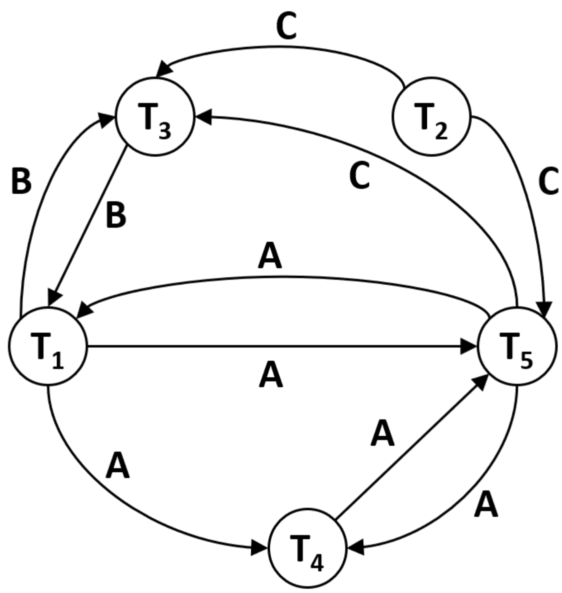
$R_{222}$ and $R_1$ share the same $C \to D$

| | $A$ | $B$ | $C$ | $D$ | $E$ | $G$ | $H$ | $I$ | $J$ |
|---|---|---|---|---|---|---|---|---|---|
| $R_1$ | | | a | a | | | | | |
| $R_{211}$ | a | | a | | | | a | | |
| $R_{212}$ | | a | | | | a | a | | |
| $R_{221}$ | | | | | a | a | | a | |
| $R_{222}$ | a | a | a | a | a | a | a | a | a |

The last row is all a, so it is a lossless decomposition.

Question 2:
1) At checkpoint, T1 T3 T4 start, T2 commits. At crash point, T1 T5 commit.
So, T1 T5 redo, T3 T4 undo. (T3 undo can be omitted, as no write operation for T3 before the crash point.)

2) Not conflict serializable.




3) Only deadlock part is shown

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| T1 | WL(A) | R(A) | | | | | WL(B) | Wait for T3 | | |
| T3 | | | WL(B) | R(B) | | | | WL(C) | Wait for T5 | |
| T5 | | | | | WL(C) | R(C) | | | WL(A) | Wait for T1 |

4) Answer is not unique

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1 | WL(A) | R(A) | WL(B) | R(B) | W(A) | UL(A) | W(B) | UL(B) | | | | |
| T2 | | | | | | | | | WL(C) | R(C) | W(C) | UL(C) |
| T3 | | | | | | | | | | | | |
| T4 | | | | | | | | | | | | |
| T5 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1 | | | | | | | | | | | | |
| T2 | | | | | | | | | | | | |
| T3 | WL(B) | R(B) | WL(C) | R(C) | W(B) | UL(B) | W(C) | UL(C) | | | | |
| T4 | | | | | | | | | WL(D) | R(D) | W(D) | UL(D) |
| T5 | | | | | | | | | | | | |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| T1 | | | | | | | | | | | | |
| T2 | | | | | | | | | | | | |
| T3 | | | | | | | | | | | | |
| T4 | WL(A) | R(A) | W(A) | UL(A) | | | | | | | | |
| T5 | | | | | WL(C) | R(C) | WL(A) | R(A) | W(C) | UL(C) | W(A) | UL(A) |