

**Question 1: Functional Dependencies I ..... [15 points]**

Consider the following legal instance of a relational schema  $S$  with attributes  $XYZ$ :

S	X	Y	Z
	$m$	20	T
	$m$	10	F
	$o$	30	T
	$n$	30	T
	$o$	20	T

Table 1: Legal instance of schema  $S$  for question 2.1

- (a) Which of the following dependencies are *violated* by the instances of  $S$  in Table 1?
- i. [2 points] ☐ Yes ☐ No :  $X \rightarrow Y$  is violated.
  - ii. [2 points] ☐ Yes ☐ No :  $Z \rightarrow X$  is violated.
  - iii. [2 points] ☐ Yes ☐ No :  $Y \rightarrow Z$  is violated.
  - iv. [2 points] ☐ Yes ☐ No :  $XY \rightarrow Z$  is violated.
  - v. [2 points] ☐ Yes ☐ No :  $YZ \rightarrow X$  is violated.
  - vi. [2 points] ☐ Yes ☐ No :  $XZ \rightarrow Y$  is violated.
- (b) [3 points] By only observing the instance of  $S$  in Table 1, can you identify the functional dependencies that hold on schema  $S$ ? Why?
- ☐ Yes ☐ No
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## Question 2: Functional Dependencies II ..... [32 points]

For the next set of questions consider the relational schema  $\mathcal{R} = \{P, Q, R, S, T, U, V, W\}$  and the set of functional dependencies FD:

$$Q \rightarrow U \quad (1)$$

$$U \rightarrow V \quad (2)$$

$$PQ \rightarrow WST \quad (3)$$

$$SU \rightarrow TR \quad (4)$$

$$VT \rightarrow RW \quad (5)$$

$$R \rightarrow W \quad (6)$$

(a) [8 points] Which of the following is a minimum cover of the FD? Mark all that qualify; if none, mark accordingly, and give your *own*. answer.

- i. The given FDs (Eq 1-6), is a minimum cover already.
- ii.  $\{Q \rightarrow U, U \rightarrow V, PQ \rightarrow S, SU \rightarrow T, SU \rightarrow R, VT \rightarrow R, VT \rightarrow W, R \rightarrow W\}$
- iii.  $\{Q \rightarrow U, U \rightarrow V, PQ \rightarrow S, SU \rightarrow T, PQ \rightarrow W, VT \rightarrow R, PQ \rightarrow T, R \rightarrow W\}$
- iv.  $\{Q \rightarrow U, U \rightarrow V, PQ \rightarrow S, SU \rightarrow T, VT \rightarrow R, R \rightarrow W\}$
- v.  $\{Q \rightarrow U, U \rightarrow V, PQ \rightarrow S, SU \rightarrow T, SU \rightarrow R, VT \rightarrow R, PQ \rightarrow T, R \rightarrow W\}$
- vi. none of the above - the cover is \_\_\_\_\_

(b) Yes/No: Which of the following functional dependencies can be deduced, from the above set of functional dependencies (Eq. (1)-(6))?

- i. [3 points] ☐ Yes ☐ No :  $Q \rightarrow V$
- ii. [3 points] ☐ Yes ☐ No :  $QU \rightarrow R$
- iii. [3 points] ☐ Yes ☐ No :  $SQ \rightarrow T$
- iv. [3 points] ☐ Yes ☐ No :  $SQ \rightarrow W$
- v. [3 points] ☐ Yes ☐ No :  $PQ \rightarrow R$
- vi. [3 points] ☐ Yes ☐ No :  $VT \rightarrow Q$

(c) [3 points] True or False: The attribute closure  $\{Q\}^+$  is  $\{Q, U, V\}$ .

☐ True ☐ False

(d) [3 points] True or False: The attribute closure  $\{PQ\}^+$  is  $\{P, Q, W, S, T\}$ .

☐ True ☐ False

**Question 3: Decompositions.....[20 points]**

For this set of questions, consider the relation with attributes,  $\mathcal{X} = \{A, B, C, D, E, F\}$ , Let the following functional dependencies  $FD$  be defined over the relation  $\mathcal{X}$ :

$$A \rightarrow B$$

$$B \rightarrow CD$$

$$E \rightarrow F$$

- (a) **[2 points]** Provide the attribute closure of  $\{AB\}$ .
- (b) Consider the decomposition  $AB, BCD, EF$ . Mark 'True' or 'False':
- i. **[3 points]** ☐ True ☐ False : It is lossless
  - ii. **[3 points]** ☐ True ☐ False : It is dependency-preserving
- (c) Consider the decomposition  $AB, BCDF, EF$ . Mark 'True' or 'False':
- i. **[3 points]** ☐ True ☐ False : It is lossless
  - ii. **[3 points]** ☐ True ☐ False : It is dependency-preserving
- (d) Consider the decomposition  $ABCEF, EBD$ . Mark 'True' or 'False':
- i. **[3 points]** ☐ True ☐ False : It is lossless
  - ii. **[3 points]** ☐ True ☐ False : It is dependency-preserving

**Question 4: Normal Forms.....[33 points]**

Consider the relation with attributes,  $\mathcal{E} = \{P, Q, R, S\}$ . Suppose that the following functional dependencies hold:

$$PQ \rightarrow R \quad (7)$$

$$PQ \rightarrow S \quad (8)$$

$$R \rightarrow P \quad (9)$$

$$S \rightarrow Q \quad (10)$$

- (a) **[6 points]** List *all* the candidate key(s) for  $\mathcal{E}$ .
- (b) **[2 points]** Is the relation  $\mathcal{E}$  in BCNF? ☐ Yes ☐ No
- (c) From the list below, select all applicable choices to justify whether  $\mathcal{E}$  is (or is not) in BCNF.

**Note:** when we refer to the *main requirement* for BCNF, we mean: *every determinant is a super key*.

- i. **[1 point]** ☐ True ☐ False : All FD's satisfy the main requirement.
- ii. **[1 point]** ☐ True ☐ False : FD (7) violates the main requirement.
- iii. **[1 point]** ☐ True ☐ False : FD (8) violates the main requirement.
- iv. **[1 point]** ☐ True ☐ False : FD (9) violates the main requirement.
- v. **[1 point]** ☐ True ☐ False : FD (10) violates the main requirement.
- (d) **[2 points]** Is the relation  $\mathcal{E}$  in 3NF? ☐ Yes ☐ No
- (e) From the list below, select all applicable choices to justify whether  $\mathcal{E}$  is (or is not) in 3NF.

**Note:** when we refer to the *secondary requirement* for 3NF, we mean: *for every FD  $X \rightarrow A$ ,  $A$  is part of a candidate key*.

- i. **[1 point]** ☐ True ☐ False : All FD's satisfy the secondary requirement.
- ii. **[1 point]** ☐ True ☐ False : FD (7) violates the secondary requirement.
- iii. **[1 point]** ☐ True ☐ False : FD (8) violates the secondary requirement.
- iv. **[1 point]** ☐ True ☐ False : FD (9) violates the secondary requirement.
- v. **[1 point]** ☐ True ☐ False : FD (10) violates the secondary requirement.
- (f) **[5 points]** Give a 3NF decomposition of  $\mathcal{E}$  that is lossless, dependency preserving, and has as few tables as possible.
- (g) **[8 points]** Give a BCNF decomposition of  $\mathcal{E}$  that is lossless, and has as few tables as possible.