CSC343, April 2021, term test
sample solution

Question #1 Submit your solutions as PDF file q1-solution.pdf.

(a) (2 points) For relation $R(A, B, C, D, E)$ and the following functional dependencies:

$$A \to D,\ B \to DE,\ C \to E,\ E \to A$$

...choose the correct answer for each part below.

i. AC is a key for R — $\boxed{AC \text{ is **not** a key for } R}$

ii. $\boxed{CB \text{ is a key for } R}$ — CB is **not** a key for R

iii. CE is a key for R — $\boxed{CE \text{ is **not** a key for } R}$

iv. CBA is a key for R — $\boxed{CBA \text{ is **not** a key for } R}$

(b) (2 points) Consider relation $R(A, B, C, D, E)$ and the following functional dependencies:

$$B \to CE,\ CE \to A$$

...For each instance of R below, choose the best description from the three choices beside it.

i.

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

$\boxed{\text{valid, without redundant data}}$

invalid

valid, with redundant data

ii.

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

valid, without redundant data

$\boxed{\text{invalid}}$

valid, with redundant data

iii.

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

valid, without redundant data

invalid

$\boxed{\text{valid, with redundant data}}$

iv.

A	B	C	D	E
1	2	3	2	1

$\boxed{\text{valid, without redundant data}}$

invalid

valid, with redundant data

(c) (3 points) Consider relation $R(A, B, C, D, E)$ and the following functional dependencies:

$$BC \rightarrow D,\ C \rightarrow E,\ E \rightarrow A$$

Suppose we have an instance of R that has, as its first tuple, $\langle 0, 1, 2, 3, 4\rangle$. Consider each possibility below for a second tuple that we might insert. For each possibility indicate whether it could be, or could **not** be, that second tuple, yielding a valid instance of R.

i.	$\langle 0, 2, 1, 3, 3\rangle$	$\boxed{\text{This could be the second tuple.}}$	This could **not** be the second tuple.
ii.	$\langle 3, 2, 1, 0, 4\rangle$	This could be the second tuple.	$\boxed{\text{This could not be the second tuple.}}$
iii.	$\langle 0, 3, 2, 1, 4\rangle$	$\boxed{\text{This could be the second tuple.}}$	This could **not** be the second tuple.
iv.	$\langle 0, 1, 2, 3, 4\rangle$	This could be the second tuple.	$\boxed{\text{This could not be the second tuple.}}$
v.	$\langle 1, 0, 2, 4, 3\rangle$	This could be the second tuple.	$\boxed{\text{This could not be the second tuple.}}$
vi.	$\langle 0, 3, 2, 1, 4\rangle$	$\boxed{\text{This could be the second tuple.}}$	This could **not** be the second tuple.

(d) (2 points) Consider relation $R(A, B, C, D, E, F)$ and the following functional dependencies:

$$B \rightarrow CD,\ D \rightarrow EA,\ C \rightarrow DA,\ FA \rightarrow B$$

Indicate which of the functional dependencies below, if any, violate BCNF for R?

i.	$B \rightarrow CD$	$\boxed{\text{violates BCNF}}$	Does not violate BCNF
ii.	$D \rightarrow EA$	$\boxed{\text{violates BCNF}}$	Does not violate BCNF
iii.	$C \rightarrow DA$	$\boxed{\text{violates BCNF}}$	Does not violate BCNF
iv.	$FA \rightarrow B$	violates BCNF	$\boxed{\text{Does not violate BCNF}}$

(e) (3 points) Consider relation $R(A, B, C, D, E)$ and the following functional dependencies:

$$S = \{BE \rightarrow CD,\ C \rightarrow E,\ A \rightarrow D,\ E \rightarrow A\}$$

Indicate which of the functional dependencies below follow from S.

i.	$BC \rightarrow A$	$\boxed{\text{This follows from } S.}$	This does **not** follow from S.
ii.	$CE \rightarrow BA$	This follows from S.	$\boxed{\text{This does not follow from } S.}$
iii.	$BE \rightarrow A$	$\boxed{\text{This follows from } S.}$	This does **not** follow from S.
iv.	$BA \rightarrow C$	This follows from S.	$\boxed{\text{This does not follow from } S.}$
v.	$AC \rightarrow B$	This follows from S.	$\boxed{\text{This does not follow from } S.}$
vi.	$CBDA \rightarrow E$	$\boxed{\text{This follows from } S.}$	This does **not** follow from S.

(f) (2 points) Consider the relation $R(A, B, C, D, E, F)$ with the following set of dependencies:

$$S = \{D \to FA,\ AC \to B,\ F \to C,\ BD \to E\}$$

We are beginning the BCNF decomposition algorithm and we are about to make the first split. For each possible first split indicate which two relations R should be split into. Recall that the order of the attributes makes no difference.

i. If we choose dependency $D \to FA$, which two relations should R be decomposed into?

   $\boxed{\text{N/A, because it is invalid to split on this dependency}}$ — DF and ABCDEF

   DFA and DBCE — DFAC and DFBE

   DFAC and ACBE — none of the above

ii. If we choose dependency $AC \to B$, which two relations should R be decomposed into?

   N/A, because it is invalid to split on this dependency — $\boxed{\text{ACB and ACDEF}}$

   ACBD and ACEF — AC and BDEF

   ACBE and ACBDF — none of the above

iii. If we choose dependency $F \to C$, which two relations should R be decomposed into?

   N/A, because it is invalid to split on this dependency — FCB and FADE

   $\boxed{\text{FC and FABDE}}$ — FC and CABDE

   FCA and FBDE — none of the above

iv. If we choose dependency $BD \to E$, which two relations should R be decomposed into?

   $\boxed{\text{N/A, because it is invalid to split on this dependency}}$ — BD and BDACEF

   BDE and BDACF — BDAC and BDEF

   BDEA and BDCF — none of the above

Question #2 (6 points)

Relation $R(G, H, I, J, K, L)$ has dependencies

$$S = \{HI \to K, GHJ \to L, IJ \to GH, HJ \to IK, HIJ \to GL, H \to I, \}$$

Find a minimal basis for S. Show your steps, and if you take a short-cut explain it. Order the attributes of the LHS and RHS of each FD you derive in alphabetical order, for example $LK \to JH$ should be rewritten as $KL \to HJ$. Then list the FDs in alphabetical order by LHS, break ties (if necessary) with RHS. Submit your answer as PDF file q2-solution.pdf.

Note: We announced, and corrected, a clerical error 30 minutes after the test started (3:30). However, some students didn't take this into account, so we have attempted to graded them based on their misapprehension of the question.

Version 1: Include attribute O

Relation $R(G, H, I, J, K, L, O)$ has dependencies S:

$$S = \{HI \to K, GHI \to O, IJ \to GH, HJ \to IK, HIJ \to GL, H \to I\}$$

Find the minimal basis for S.

Step 1: We'll first **simplify** FDs to singleton right-hand sides. We'll also order and number the resulting FDs for easy reference, and call this set S_1:

(a) $GHI \to O$
(b) $H \to I$
(c) $HI \to K$
(d) $HIJ \to G$
(e) $HIJ \to L$
(f) $HJ \to I$
(g) $HJ \to K$
(h) $IJ \to G$
(i) $IJ \to H$

Step 2: We next try to **reduce the LHS** of FDs with multiple attributes on the LHS. For these closures, we will close over the full set S_1, <u>including</u> the FD being considered for simplification.

(a) $GHI \to O$
- $G^+ = G$
- $H^+ = HIK$
- $I^+ = I$
- $GI^+ = GI$
- $GH^+ = GHIKO$, so we can reduce the LHS: $GH \to O$ ✓

(b) $H \to I$
LHS is singleton, nothing to reduce.

(c) $HI \to K$
- $H^+ = HIK$, so we can reduce the LHS: $H \to K$ ✓

(d) $HIJ \to G$
- $H^+ = HIK$
- $I^+ = I$
- $J^+ = J$
- $HI^+ = HIK$
- $HJ^+ = GHIJKL$, so we can reduce the LHS: $HJ \to G$ ✓

(e) $HIJ \to L$
- $H^+ = HIK$
- $I^+ = I$
- $J^+ = J$
- $HI^+ = HIK$
- $HJ^+ = GHIJKL$, so we can reduce the LHS: $HJ \to L$ ✓

(f) $HJ \to I$
- $H^+ = HIK$, so we can reduce the LHS: $H \to I$ (duplicate) ✓

(g) $HJ \to K$
- $H^+ = HIK$, so we can reduce the LHS: $H \to K$ (duplicate) ✓

(h) $IJ \to G$
- $I^+ = I$
- $J^+ = J$

Nothing to reduce.

(i) $IJ \to H$
- $I^+ = I$
- $J^+ = J$

Nothing to reduce.

We call the revised set of FDs after reducing LHS and removing duplicates S_2:

(a) $GH \to O$
(b) $H \to I$
(c) $H \to K$
(d) $HJ \to G$
(e) $HJ \to L$
(f) $IJ \to G$
(g) $IJ \to H$

Step 3: Eliminate redundant FDs.

FD	Exclude from S_2	Closure	Decision
1. $GH \to O$	1	$GH^+_{S_2-1} = GH$	keep
2. $H \to I$	2	$H^+_{S_2-2} = HK$	keep
3. $H \to K$	3	$H^+_{S_2-3} = HI$	keep
4. $HJ \to G$	4	$HJ^+_{S_2-4} = HJL$	keep
5. $HJ \to L$	5	$HJ^+_{S_2-5} = GHIJKO$	keep
6. $IJ \to G$	6	$IJ^+_{S_2-6} = GHIJKL$	remove
7. $IJ \to H$	6,7	$IJ^+_{S_2-6-7} = IJ$	keep

No further simplifications are possible, so the following set S_3 is a minimal basis (ordered alphabetically):

(a) $GH \to O$
(b) $H \to I$
(c) $H \to K$
(d) $HJ \to G$
(e) $HJ \to L$
(f) $IJ \to H$

Version 2a: Remove attribute O, replace $GHI \to O$ with $GHJ \to L$, strict ordering.

Relation $R(G, H, I, J, K, L)$ has dependencies S:

$$S = \{HI \to K, GHJ \to L, IJ \to GH, HJ \to IK, HIJ \to GL, H \to I\}$$

Find the minimal basis for S.

Step 1: We'll first **simplify** FDs to singleton right-hand sides. We'll also **order and number** the resulting FDs for easy reference, and call this set S_1:

(a) $GHJ \to L$
(b) $H \to I$
(c) $HI \to K$
(d) $HIJ \to G$
(e) $HIJ \to L$
(f) $HJ \to I$
(g) $HJ \to K$
(h) $IJ \to G$
(i) $IJ \to H$

Step 2: We next try to **reduce the LHS** of FDs with multiple attributes on the LHS. For these closures, we will close over the full set S_1, including the FD being considered for simplification.

(a) $GHJ \to L$
- $G^+ = G$
- $H^+ = HIK$
- $J^+ = J$
- $GH^+ = GHIK$
- $GJ^+ = GJ$
- $HJ^+ = GHIJKL$, so we can reduce the LHS: $HJ \to L$ ✓

(b) $H \to I$
LHS is singleton, nothing to reduce.

(c) $HI \to K$
- $H^+ = HIK$, so we can reduce the LHS: $H \to K$ ✓

(d) $HIJ \to G$
- $H^+ = HIK$
- $I^+ = I$

- $J^+ = J$
- $HI^+ = HIK$
- $HJ^+ = GHIJKL$, so we can reduce the LHS: $HJ \to G$ ✓

(e) $HIJ \to L$
- $H^+ = HIK$
- $I^+ = I$
- $J^+ = J$
- $HI^+ = HIK$
- $HJ^+ = GHIJKL$, so we can reduce the LHS: $HJ \to L$ ✓

(f) $HJ \to I$
- $H^+ = HIK$, so we can reduce the LHS: $H \to I$ (duplicate) ✓

(g) $HJ \to K$
- $H^+ = HIK$, so we can reduce the LHS: $H \to K$ (duplicate) ✓

(h) $IJ \to G$
- $I^+ = I$
- $J^+ = J$

Nothing to reduce.

(i) $IJ \to H$
- $I^+ = I$
- $J^+ = J$

Nothing to reduce.

We call the revised set of FDs after reducing LHS and removing duplicates and ordering S_2:

(a) $H \to I$
(b) $H \to K$
(c) $HJ \to G$
(d) $HJ \to L$
(e) $IJ \to G$
(f) $IJ \to H$

Step 3: Eliminate redundant FDs.

FD	Exclude from S_2	Closure	Decision
1. $H \to I$	1	$H^+_{S_2-1} = HK$	keep
2. $H \to K$	2	$H^+_{S_2-2} = HI$	keep
3. $HJ \to G$	3	$HJ^+_{S_2-3} = GHIJKL$	discard
4. $HJ \to L$	3,4	$HJ^+_{S_2-3-4} = GHIJK$	keep
5. $IJ \to G$	3,5	$IJ^+_{S_2-3-5} = HIJKL$	keep
6. $IJ \to H$	3,6	$IJ^+_{S_2-3-6} = GIJ$	keep

No further simplifications are possible, so the following set S_3 is a minimal basis (ordered alphabetically):

(a) $H \to I$
(b) $H \to K$
(c) $HJ \to L$
(d) $IJ \to G$

(e) $IJ \to H$

Version 2b: Remove attribute O, replace $GHI \to O$ with $GHJ \to L$, keep original FD order.

Relation $R(G, H, I, J, K, L)$ has dependencies S:

$$S = \{HI \to K, GHJ \to L, IJ \to GH, HJ \to IK, HIJ \to GL, H \to I\}$$

Find the minimal basis for S.

Step 1: We'll first **simplify** FDs to singleton right-hand sides. We'll also **order and number** the resulting FDs for easy reference, and call this set S_1:

(a) $HI \to K$
(b) $GHJ \to L$
(c) $IJ \to G$
(d) $IJ \to H$
(e) $HJ \to I$
(f) $HJ \to K$
(g) $HIJ \to G$
(h) $HIJ \to L$
(i) $H \to I$

Step 2: We next try to **reduce the LHS** of FDs with multiple attributes on the LHS. For these closures, we will close over the full set S_1, including the FD being considered for simplification (same as Version 2a step 2).

(a) $HI \to K$
- $H^+ = HIK$, so we can reduce the LHS: $H \to K$ ✓

(b) $GHJ \to L$
- $G^+ = G$
- $H^+ = HIK$
- $J^+ = J$
- $GH^+ = GHIK$
- $GJ^+ = GJ$
- $HJ^+ = GHIJKL$, so we can reduce the LHS: $HJ \to L$ ✓

(c) $IJ \to G$
- $I^+ = I$
- $J^+ = J$

Nothing to reduce.

(d) $IJ \to H$
- $I^+ = I$
- $J^+ = J$

Nothing to reduce.

(e) $HJ \to I$
- $H^+ = HIK$, so we can reduce the LHS: $H \to I$ (duplicate) ✓

(f) $HJ \to K$
- $H^+ = HIK$, so we can reduce the LHS: $H \to K$ (duplicate) ✓

(g) $HIJ \to G$
- $H^+ = HIK$
- $I^+ = I$
- $J^+ = J$
- $HI^+ = HIK$
- $HJ^+ = GHIJKL$, so we can reduce the LHS: $HJ \to G$ ✓
- $IJ^+ = GHIJKL$, so we can also choose to reduce the LHS producing $IJ \to G$ instead, if this subset is considered first. ✓

(h) $HIJ \to L$
- $H^+ = HIK$
- $I^+ = I$
- $J^+ = J$
- $HI^+ = HIK$
- $HJ^+ = GHIJKL$, so we can reduce the LHS: $HJ \to L$ ✓
- $IJ^+ = GHIJKL$, so we can also choose to reduce the LHS producing $IJ \to L$ instead, if this subset is considered first. ✓

(i) $H \to I$
LHS is singleton, nothing to reduce.

We call the revised set of FDs after reducing LHS and removing duplicates and ordering S_2:

(a) $H \to K$
(b) $HJ \to L$
(c) $IJ \to G$
(d) $IJ \to H$
(e) $H \to I$
(f) $HJ \to G$

Step 3: Eliminate redundant FDs.

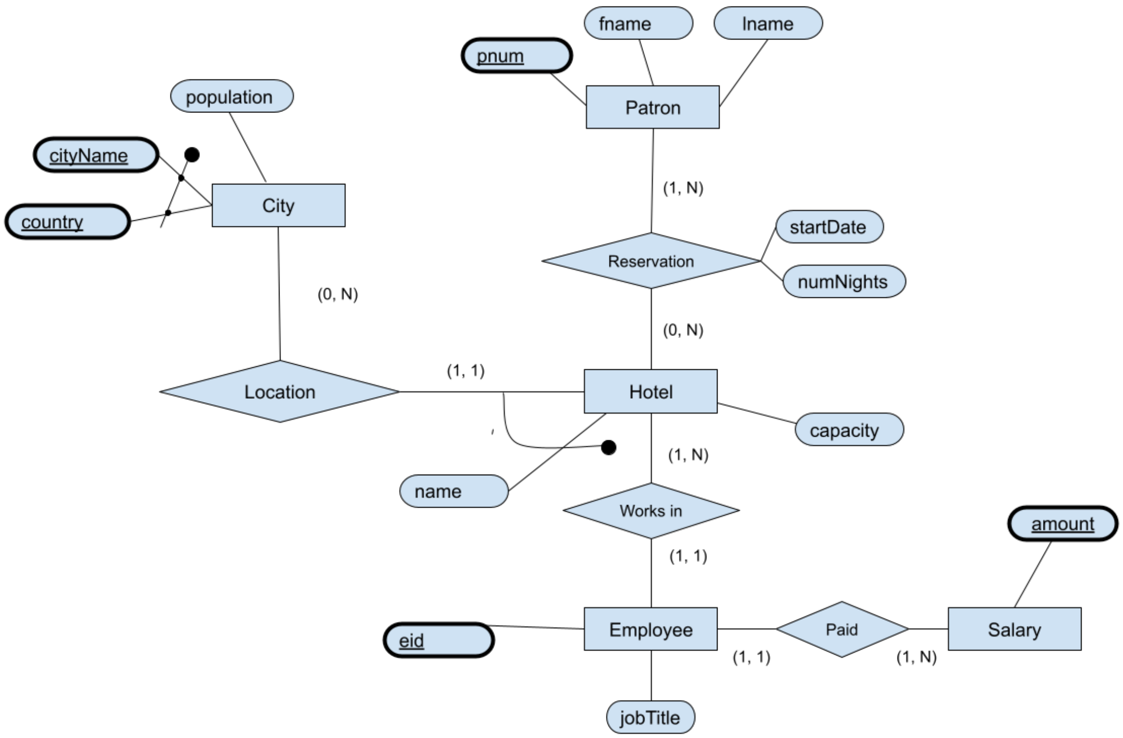
FD	Exclude from S_2	Closure	Decision
1. $H \to K$	1	$H^+_{S_2-1} = HI$	keep
2. $HJ \to L$	2	$HJ^+_{S_2-2} = GHIJK$	keep
3. $IJ \to G$	3	$IJ^+_{S_2-3} = GHIJKL$	discard
4. $IJ \to H$	3,4	$IJ^+_{S_2-3-4} = IJ$	keep
5. $H \to I$	3,5	$H^+_{S_2-3-5} = HK$	keep
6. $HJ \to G$	3,6	$HJ^+_{S_2-3-6} = HIJKL$	keep

No further simplifications are possible, so the following set S_3 is a minimal basis (unordered):

(a) $H \to K$
(b) $HJ \to L$ (may see $IJ \to L$ if in reducing $HIJ \to L$, they explored IJ first)
(c) $IJ \to H$
(d) $H \to I$
(e) $HJ \to G$ (may see $IJ \to G$ if in reducing $HIJ \to G$ they explored IJ first)

Question #3 Submit your solutions as PDF file q3-solution.pdf.

Consider the following Entity-Relationship Diagram.
Note that in this diagram the keys are underlined and have a bold outline.



(a) (3 points) Which of these cardinalities is possible for the 'Works In' relationship?

$\|hotel\|$	$\|worksIn\|$	$\|employee\|$	Is it possible?
1	0	0	YES $\boxed{\text{NO}}$
3	3	1	YES $\boxed{\text{NO}}$
1	1	3	YES $\boxed{\text{NO}}$
0	0	0	$\boxed{\text{YES}}$ NO
6	8	12	YES $\boxed{\text{NO}}$
4	8	8	$\boxed{\text{YES}}$ NO

(b) (2 points) Define a relation called 'Reservation' that corresponds to the relationship set Reservation from the ER diagram. Provide its name, attributes and keys using relational model notation, *R(a,b,c)*. (To indicate a key, underline all attributes that are part of the key using a single line.) However, if Reservation can be collapsed into another relation, **instead** show the modified relation. If it should not be collapsed, explain why.

Reservation($\underline{\text{hotelName,city,country,patron}}$,startDate,numNights)
Many-to-many cardinality will not allow for collapsing.

(c) (1 points) Given your answer to part b, express the 'minimum 1' constraint on Patron's involvement in the Reservation relationship, using the relational model notation for integrity constraints, $A[b] \subseteq C[d]$.

Patron[pnum] $\subseteq$ Reservation[patron]

(d) (2 points) Without making any simplifications/modifications to the ER diagram itself, define a relation 'Paid' that corresponds to the relationship set Paid from the ER diagram. Provide its name, attributes and keys using relational model notation (as in part b above).
However, if Paid can be collapsed into another relation, **instead** show the modified relation. If it should not be collapsed explain why.

One-to-many allows collapsing.
Employee($\underline{\text{eid}}$, jobTitle, amount)

(e) (1 points) In the ER diagram itself, is the 'Paid' relationship set necessary, or can we remove it and simplify the diagram? If we can simplify the diagram, explain what you would change on the diagram (you do not need to draw it out). Explain **all** the changes you would make. If we can't simplify it and it is necessary, explain why.

It can be simplified as so:
1. Remove the Paid relationship set,
2. Remove the Salary entity set,
3. Move the salary 'amount' to be an attribute of Employee.

Question #4 Open the SQL DDL schema q4.txt, which represents a slightly modified version of the airports schema from Assignment 2. Complete the questions listed at the bottom of the file. You will be required to edit the file in a text editor.

Submit your edited file on Markus as q4-solution.txt. Do not submit any PDFs or image files for this question.

```
1)
In table Flight:
plane CHAR(5) REFERENCES Plane ON UPDATE CASCADE ON DELETE SET NULL

2)
In table Booking:
UNIQUE (pass_id, flight_id)

3)
In table Plane:
check (capacity_economy >= capacity_business * 2)

4)
In table Passenger:
email VARCHAR(40)
OR
email TEXT check(char_length(email)<=40)

5)
In tables Departure, Arrival, and Booking:
flight_id ..... ON DELETE CASCADE
```