

## NATIONAL UNIVERSITY OF SINGAPORE

SCHOOL OF COMPUTING  
FINAL ASSESSMENT FOR  
Semester 1 AY2024/2025

## IT5008 Database Design and Programming

November 2024

Time Allowed 120 minutes

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INSTRUCTIONS TO CANDIDATES

1. This assessment paper contains **23** questions and comprises **8** printed pages, including this page.
2. More specific instructions *may* be given at the beginning of each section. Please read them carefully.
3. Write all your answers in the answer sheet provided. Please read the additional instruction for multiple choice (MCQ) and multiple response (MRQ) questions.
  - Any answer not in the space provided will not be graded.
  - For MCQ and MRQ, **shade your answer in the corresponding bubble on the answer sheet.**
  - For MCQ, if multiple answers are equally appropriate, pick one and shade **ONLY** the chosen answer on the answer sheet. Do **NOT** shade more than one answer.
  - For MRQ, shade **ALL** correct answers. Partial marks *may* be given, but not guaranteed.
  - If there are no correct answer or no appropriate choices, shade X in the answer sheet. No partial mark given if X is chosen.
4. Shade and write your student number in the answer sheet. Do **NOT** write your name.
5. The total marks for this assessment is 80. Answer **ALL** questions.
6. This is a **CLOSED-BOOK** assessment. You are only allowed to refer to one double-sided A4-size paper.
7. All SQL query in this assessment paper are run on PostgreSQL 16.
8. We will use the monospace **NULL** to represent NULL-values. We will represent string with single-quote 'string'.
9. The last page is left blank. You may use them for your own work.

Question	Points
1 - 10	30
11 - 20	30
21 - 22	8
23	12
TOTAL	80

## Functional Dependencies and Normal Forms

For the next **ten (10)** questions, we will be using the following relation and set of functional dependencies.

$$R = \{A, B, C, D, E\}$$

$$\Sigma = \{ \{C, E\} \rightarrow \{A, B\}, \{A, B, C\} \rightarrow \{A, D\}, \{D, E\} \rightarrow \{A, B, E\}, \{D\} \rightarrow \{A, C\}, \\ \{A, C\} \rightarrow \{A, B\}, \{A, D\} \rightarrow \{B\}, \{C, D\} \rightarrow \{A, B\} \}$$

1. (3 points) **(MRQ)** Select **ALL** the attributes in the *closure* of  $\{A, C\}$  (i.e.,  $\{A, C\}^+$ ).

A.  $A$                       B.  $B$                       C.  $C$                       D.  $D$                       E.  $E$

Select X if there is no answer.

2. (3 points) **(MRQ)** Select **ALL** the functional dependencies that are *logically entailed* by  $\Sigma$ .

A.  $\{A, B\} \rightarrow \{C\}$   
 B.  $\{B, C\} \rightarrow \{D\}$   
 C.  $\{C, D\} \rightarrow \{E\}$   
 D.  $\{D, E\} \rightarrow \{A\}$   
 E.  $\{A, E\} \rightarrow \{B\}$

Select X if there is no answer.

3. (3 points) **(MRQ)** Select **ALL** the *superkeys* of  $R$  with  $\Sigma$  from the choice below.

A.  $\{A, B, C\}$   
 B.  $\{B, C, D\}$   
 C.  $\{C, D, E\}$   
 D.  $\{A, D, E\}$   
 E.  $\{A, B, E\}$

Select X if there is no answer.

4. (3 points) **(MRQ)** Select **ALL** the *candidate keys* of  $R$  with  $\Sigma$  from the choice below.

A.  $\{A, B\}$   
 B.  $\{A, E\}$   
 C.  $\{B, E\}$   
 D.  $\{C, E\}$   
 E.  $\{D, E\}$

Select X if there is no answer.

5. (3 points) **(MRQ)** Select **ALL** the *prime attributes* of  $R$  with  $\Sigma$ .

A.  $A$                       B.  $B$                       C.  $C$                       D.  $D$                       E.  $E$

Select X if there is no answer.

6. (3 points) **(MRQ)** Select **ALL** the functional dependencies below that are in the *projection* of  $R$  into  $R_1 = \{B, D, E\}$ .

A.  $\{B\} \rightarrow \{D\}$   
 B.  $\{D, E\} \rightarrow \{B\}$   
 C.  $\{D\} \rightarrow \{B\}$   
 D.  $\{E\} \rightarrow \{B\}$   
 E.  $\{E\} \rightarrow \{D\}$

Select X if there is no answer.

7. (3 points) **(MRQ)** Select **ALL** the functional dependencies below that violates the BCNF property of  $R$  with  $\Sigma$ .

- A.  $\{A, B, C\} \rightarrow \{D\}$
- B.  $\{D, E\} \rightarrow \{B\}$
- C.  $\{D\} \rightarrow \{C\}$
- D.  $\{A, C\} \rightarrow \{A\}$
- E.  $\{C, D\} \rightarrow \{B\}$

Select X if there is no answer.

8. (3 points) **(MRQ)** Select **ALL** the functional dependencies below that violates the 3NF property of  $R$  with  $\Sigma$ .

- A.  $\{A, B, C\} \rightarrow \{D\}$
- B.  $\{D, E\} \rightarrow \{B\}$
- C.  $\{D\} \rightarrow \{C\}$
- D.  $\{A, C\} \rightarrow \{A\}$
- E.  $\{C, D\} \rightarrow \{B\}$

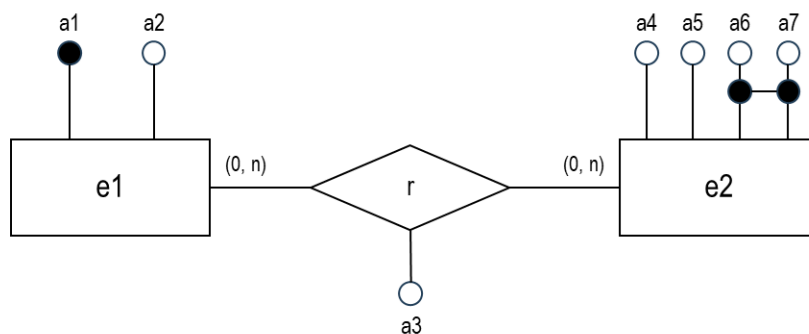
Select X if there is no answer.

9. (3 points) Find one lossless-join decomposition of  $R$  in BCNF using the BCNF decomposition algorithm introduced in the course.

10. (3 points) Find one dependency preserving lossless-join decomposition of  $R$  in 3NF using the 3NF synthesis algorithm introduced in the course.

## Schema Translation

For the next **two (2)** questions, we will be using the following relation entity-relationship diagram.



During the translation, if  $t_1$  and  $t_2$  are entity/relationship sets, if the table for  $t_1$  and  $t_2$  are merged, if the statement is correct for table  $t_1$ , then the same statement is true for table  $t_2$ .

11. (3 points) **(MRQ)** Select **ALL** the correct statement.

- A. A possible primary key of the table for  $r$  is  $a_3$ .
- B. A possible primary key of the table for  $r$  is  $a_1$ .
- C. A possible primary key of the table for  $r$  is  $(a_6, a_7)$ .
- D. A possible primary key of the table for  $r$  is  $(a_1, a_6, a_7)$ .
- E. A possible primary key of the table for  $r$  is  $(a_1, a_3, a_6, a_7)$ .

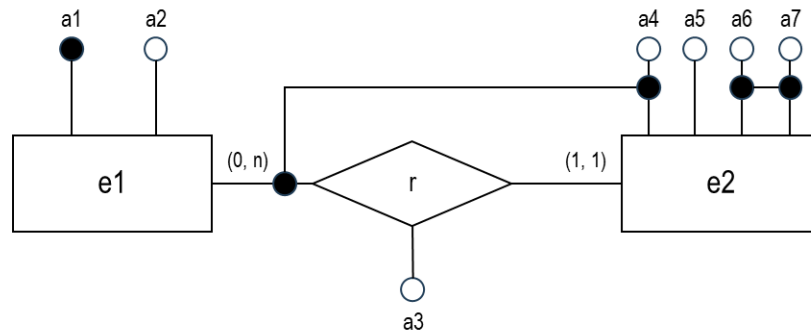
Select X if there is no answer.

12. (3 points) **(MRQ)** Select **ALL** the correct statement.

- A.  $a_1$  is the foreign key in the table  $r$  referencing  $a_1$  in table  $e_1$ .
- B.  $a_1$  is the foreign key in the table  $e_1$  referencing  $a_1$  in table  $r$ .
- C.  $a_1$  is the foreign key in the table  $e_2$  referencing  $a_1$  in table  $e_1$ .
- D.  $(a_6, a_7)$  is the foreign key in the table  $r$  referencing  $(a_6, a_7)$  in table  $e_2$ .
- E.  $(a_6, a_7)$  is the foreign key in the table  $e_2$  referencing  $(a_6, a_7)$  in table  $r$ .

Select X if there is no answer.

For the next **two (2)** questions, we will be using the following relation entity-relationship diagram.



During the translation, if  $t_1$  and  $t_2$  are entity/relationship sets, if the table for  $t_1$  and  $t_2$  are merged, if the statement is correct for table  $t_1$ , then the same statement is true for table  $t_2$ .

13. (3 points) **(MRQ)** Select **ALL** the correct statement.

- A. The table  $e_1$  is merged with the table  $r$ .
- B. The table  $e_2$  is merged with the table  $r$ .
- C. The table  $e_1$  is merged with the table  $e_2$ .
- D. The tables  $e_1$ ,  $e_2$  and  $r$  are all merged.
- E. No tables are merged.

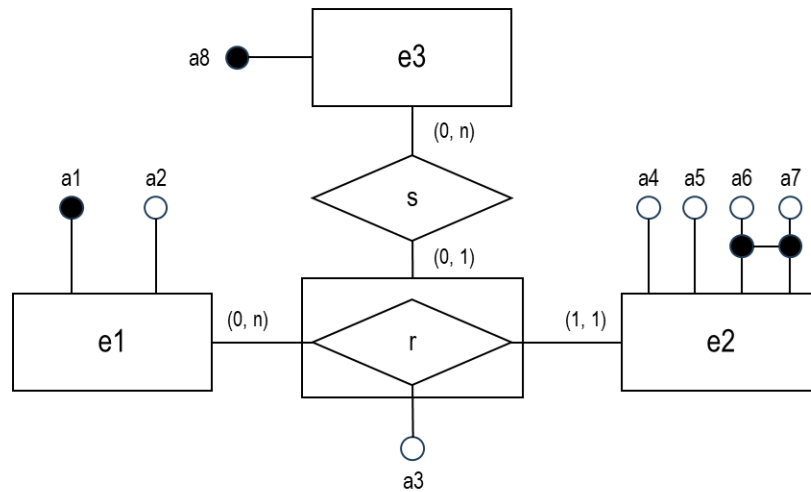
Select X if there is no answer.

14. (3 points) **(MRQ)** Select **ALL** the correct statement.

- A. A possible primary key of the table  $r$  is  $a_1$ .
- B. A possible primary key of the table  $r$  is  $a_4$ .
- C. A possible primary key of the table  $r$  is  $(a_1, a_4)$ .
- D. A possible primary key of the table  $r$  is  $(a_6, a_7)$ .
- E. A possible primary key of the table  $r$  is  $(a_1, a_6, a_7)$ .

Select X if there is no answer.

For the next **three (3)** questions, we will be using the following relation entity-relationship diagram.



During the translation, if  $t_1$  and  $t_2$  are entity/relationship sets, if the table for  $t_1$  and  $t_2$  are merged, if the statement is correct for table  $t_1$ , then the same statement is true for table  $t_2$ .

15. (3 points) **(MCQ)** How many tables are created.

- A. 6
- B. 5
- C. 4
- D. 3
- E. 2.

Select X if there is no answer.

16. (3 points) **(MRQ)** Select **ALL** the correct statement.

- A. The table  $r$  and  $e_1$  are merged.
- B. The table  $r$  and  $e_2$  are merged.
- C. The table  $r$  and  $s$  are merged.
- D. The table  $s$  and  $e_3$  are merged.
- E. No tables are merged.

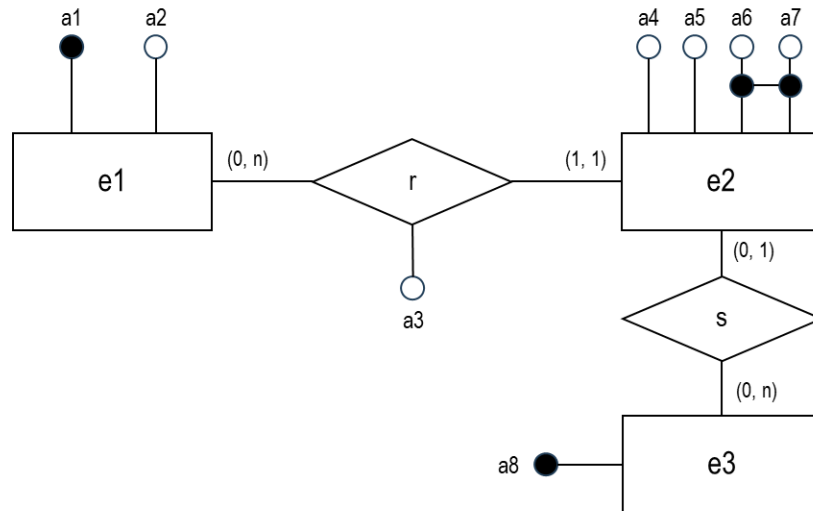
Select X if there is no answer.

17. (3 points) **(MRQ)** Select **ALL** the correct statement.

- A. A possible primary key of the table  $s$  is  $a_1$ .
- B. A possible primary key of the table  $s$  is  $(a_6, a_7)$ .
- C. A possible primary key of the table  $s$  is  $(a_1, a_6, a_7)$ .
- D. A possible primary key of the table  $s$  is  $(a_6, a_7, a_8)$ .
- E. A possible primary key of the table  $s$  is  $(a_1, a_6, a_7, a_8)$ .

Select X if there is no answer.

For the next **three (3)** questions, we will be using the following relation entity-relationship diagram.



During the translation, if  $t_1$  and  $t_2$  are entity/relationship sets, if the table for  $t_1$  and  $t_2$  are merged, if the statement is correct for table  $t_1$ , then the same statement is true for table  $t_2$ .

18. (3 points) **(MCQ)** How many tables are created.

- A. 6
- B. 5
- C. 4
- D. 3
- E. 2.

Select X if there is no answer.

19. (3 points) **(MRQ)** Select **ALL** the correct statement.

- A. A possible primary key of the table  $s$  is  $(a_1, a_6, a_7)$ .
- B. A possible primary key of the table  $s$  is  $(a_3, a_6, a_7)$ .
- C. A possible primary key of the table  $s$  is  $(a_6, a_7, a_8)$ .
- D. A possible primary key of the table  $s$  is  $(a_1, a_3, a_6, a_7)$ .
- E. A possible primary key of the table  $s$  is  $(a_1, a_3, a_6, a_7, a_8)$ .

Select X if there is no answer.

20. (3 points) **(MRQ)** Select **ALL** the correct statement.

- A. A possible primary key of the table  $e_1$  is  $a_1$ .
- B. A possible primary key of the table  $e_2$  is  $(a_6, a_7)$ .
- C. A possible primary key of the table  $e_3$  is  $a_8$ .
- D. A possible primary key of the table  $r$  is  $a_1$ .
- E. A possible primary key of the table  $r$  is  $(a_1, a_6, a_7)$ .

Select X if there is no answer.

## Relational Algebra

For the next **two (2)** questions, we will consider the following schema.

- `students(matric, sname)` with `matric` as the primary key.
- `workings(pid, matric, since)` with `(pid, matric)` as the primary key, with `workings.pid` referencing `projects.pid`, and `workings.matric` referencing `students.matric`.
- `projects(pid, pname)` with `pid` as the primary key.
- `kinds(pid, cname)` with `(pid, cname)` as the primary key and with `kinds.pid` referencing `projects.pid`.

Note that you may use the dot notation in this relational algebra.

21. (3 points) Write a relational algebra expression to find the different pairs of students (i.e., the `matric` numbers (`matric1`, `matric2`)) that are working on the same project. Note that since the same student  $s$  is always working on the same project as himself/herself, we also exclude the pair  $(s, s)$ .
22. (5 points) Write a relational algebra expression to find the oldest project id (i.e., `pid`) in the database. The oldest project is the project with the smallest `since` value. Assume you can compare `since` using the typical relational operator `<`, `>`, `<=`, `>=`, `=`, or `!=`.

Note that there may be more than one oldest project. Your relational algebra expression should produce all.

## Miscellaneous

23. (12 points) Consider the relation and set of functional dependencies.

$$R = \{A, B, C, D\}$$

$$\Sigma = \{ \{A\} \rightarrow \{B\}, \{B\} \rightarrow \{C\}, \{C\} \rightarrow \{A\}, \{D\} \rightarrow \{A\} \}$$

- (a) (4 points) Using only 3NF synthesis algorithm introduced in the lecture starting from  $\Sigma$  when computing the minimal cover, produce one lossless-join dependency preserving decomposition in 3NF of  $R$  with  $\Sigma$ .
- (b) (4 points) Is there a lossless-join dependency preserving decomposition in 3NF of  $R$  with  $\Sigma$  such that all of the following is satisfied?

- The number of fragments is fewer than your answer in part (a) above.
- Each fragment is in 3NF.

If there is, provide such decomposition (i.e., provide the fragments). Otherwise, briefly explain why those are not possible.

- (c) (4 points) Provide a `CREATE TABLE` statement to enforce the functional dependencies for your answer in part (b) if your answer in part (b) is different from part (a). Otherwise, provide a `CREATE TABLE` statement to enforce the functional dependencies for your answer in part (a).

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END OF PAPER