

1. This examination paper contains **THREE (3)** exercises and comprises **ELEVEN (11)** printed pages.
2. Answer **ALL** questions.
3. Answer **ALL** questions on the OCR form or within the space provided **ONLY**, as indicated.
4. **Unnecessary** comments will be penalised.
5. This is a **Closed Book** examination.
6. **Please write your Matriculation Number Below.**

[illegible]

EXERCISE	MARKS	REMARK
E I (40)		OCR
E II (30)		
E III (30)		
Total (100)		

This is a series of multiple choice questions (questions 1 to 20) and short essay questions (questions 21 to 35).

For each **multiple choice question** choose the best answer and report the corresponding choice onto the **OCR form**. Each multiple choice question is worth 2 marks. No mark is deducted for wrong answers.

For each **short essay question** give your answer **in the reserved space in the script**. Points are deducted for unnecessary comments and wrong answers but there cannot be a negative mark for a question.

Exercise I. (40 marks) Multiple choice questions. Answer on the OCR form.

For the next seven (7) questions (1 to 7) let us consider the following self-explanatory database instance reporting the container traffic of the busiest ports for 2007 and 2008 (in thousands of containers).

Table1			
Port	Country	Y2008	Y2007
Singapore	Singapore	29918	27932
Shanghai	People's Republic of China	27980	26150
Hong Kong	Hong Kong	24248	23881
Shenzhen	People's Republic of China	21414	21099
Busan	South Korea	13425	13270
Dubai	United Arab Emirates	11827	10653
Ningbo	People's Republic of China	11226	9349
Guangzhou	People's Republic of China	11001	9200
Rotterdam	Netherlands	10784	10791
Qingdao	People's Republic of China	10320	9462

Question 1. Which of the following queries finds the countries and the **total traffic** of their ports in 2008?

- SELECT Country, COUNT(Y2008) FROM Table1 GROUP BY Country
- SELECT Country, SUM(Y2008) FROM Table1 GROUP BY Country
- SELECT Country, SUM(Y2008) FROM Table1 GROUP BY Port, Country
- SELECT Country, MAX(Y2008) FROM Table1 GROUP BY Port, Country
- SELECT Country, COUNT(DISTINCT Y2008) FROM Table1 GROUP BY Country

Question 2. Which of the following queries finds the countries and the **average traffic** of their ports in 2008?

- SELECT Country, SUM(Y2008)/COUNT(Y2008) FROM Table1 GROUP BY Country
- SELECT Country, AVG(Y2008) FROM Table1 GROUP BY Country
- SELECT DISTINCT Country, AVG(Y2008) FROM Table1 GROUP BY Country
- SELECT DISTINCT Country, SUM(Y2008)/COUNT(*) FROM Table1 GROUP BY Country
- All of the above

Question 3. Which of the following sets of tuples **is the result** of the following query?

$\{ \langle X \rangle \mid \exists Y \exists Z \exists T \text{ table1}(X, Y, Z, T) \wedge Z \leq T \}$

- \emptyset
- All ports
- $\{ \langle \text{'Hong Kong'} \rangle \}$
- $\{ \langle \text{'Rotterdam'} \rangle \}$
- $\{ \langle \text{'Singapore'} \rangle, \langle \text{'Hong Kong'} \rangle, \langle \text{'Busan'} \rangle, \langle \text{'Dubai'} \rangle, \langle \text{'Rotterdam'} \rangle, \langle \text{'Qingdao'} \rangle \}$

Question 4. Which of the following sets of tuples **is included in the result** of the following query?

$\{ \langle X1, X2 \rangle \mid \exists Y \exists Z1 \exists T1 \exists Z2 \exists T2 \text{ table1}(X1, Y, Z1, T1) \wedge \text{table1}(X2, Y, Z2, T2) \wedge Z1 < Z2 \wedge T1 < T2 \}$

- $\{ \langle \text{'Qingdao'}, \text{'Shanghai'} \rangle, \langle \text{'Ningbo'}, \text{'Shanghai'} \rangle, \langle \text{'Shanghai'}, \text{'Shanghai'} \rangle \}$
- $\{ \langle \text{'Qingdao'}, \text{'Shanghai'} \rangle, \langle \text{'Ningbo'}, \text{'Shanghai'} \rangle, \langle \text{'Ningbo'}, \text{'Shenzhen'} \rangle \}$
- $\{ \langle \text{'Qingdao'}, \text{'Shanghai'} \rangle, \langle \text{'Ningbo'}, \text{'Shanghai'} \rangle, \langle \text{'Shenzhen'}, \text{'Ningbo'} \rangle \}$
- $\{ \langle \text{'Shanghai'}, \text{'Guangzhou'} \rangle, \langle \text{'Ningbo'}, \text{'Shanghai'} \rangle, \langle \text{'Ningbo'}, \text{'Shenzhen'} \rangle \}$
- $\{ \langle \text{'Rotterdam'}, \text{'Shanghai'} \rangle, \langle \text{'Ningbo'}, \text{'Shanghai'} \rangle, \langle \text{'Ningbo'}, \text{'Shenzhen'} \rangle \}$

Question 5. What is the result of the following query?

$\{ \langle X1 \rangle \mid \exists Y1 \exists Z1 \exists T1 \forall X2 \forall Z2 \forall T2 \text{ table1}(X1, Y1, Z1, T1) \wedge (\text{table1}(X2, \text{'Italy'}, Z2, T2) \Rightarrow Z1 < Z2) \}$

- a) \emptyset
- b) All ports
- c) NULL
- d) The query is unsafe
- e) The query is syntactically incorrect

Question 6. What is the result of the following query?

$\{ \langle X1 \rangle \mid \exists Y1 \exists Z1 \exists T1 \forall X2 \forall Y2 \forall Z2 \forall T2 \text{ table1}(X1, Y1, Z1, T1) \wedge (\text{table1}(X2, Y2, Z2, T2) \Rightarrow Z1 < Z2) \}$

- a) \emptyset
- b) All ports
- c) $\{ \langle \text{'Qingdao'} \rangle \}$
- d) $\{ \langle \text{'Shanghai'} \rangle \}$
- e) $\{ \langle \text{'Singapore'} \rangle, \langle \text{'Hong Kong'} \rangle, \langle \text{'Busan'} \rangle, \langle \text{'Dubai'} \rangle, \langle \text{'Rotterdam'} \rangle, \langle \text{'Qingdao'} \rangle \}$

Question 7. What is the result of the following query? (Carefully note the differences with the previous query)

$\{ \langle X1 \rangle \mid \exists Y \exists Z1 \exists T1 \forall X2 \forall Z2 \forall T2 \text{ table1}(X1, Y, Z1, T1) \wedge (\text{table1}(X2, Y, Z2, T2) \Rightarrow Z1 \leq Z2) \}$

- a) \emptyset
- b) All ports
- c) $\{ \langle \text{'Qingdao'} \rangle \}$
- d) $\{ \langle \text{'Shanghai'} \rangle \}$
- e) $\{ \langle \text{'Singapore'} \rangle, \langle \text{'Hong Kong'} \rangle, \langle \text{'Busan'} \rangle, \langle \text{'Dubai'} \rangle, \langle \text{'Rotterdam'} \rangle, \langle \text{'Qingdao'} \rangle \}$

For the next three (3) questions (8 to 10) let us consider the following schema $R(\underline{A}, \underline{B}, C)$. (A, B) is the primary key. The relation contains n tuples (n can be equal to 0).

Question 8. How many tuples are there, at most, in the result of the following query?

$R \times R$

- a) 0
- b) 1
- c) 2
- d) n
- e) n^2

Question 9. How many tuples are there, at most, in the result of the following query?

SELECT R1.C FROM R R1, R R2 WHERE R1.A = R2.A AND R1.B = R2.B

- a) 0
- b) 1
- c) 2
- d) n
- e) n^2

Question 10. Which of the following statements is true about the result of the following query?

SELECT DISTINCT R1.C FROM R R1, R R2 WHERE R1.A = R2.A AND R1.B = R2.B

- a) The result is always empty.
- b) There is exactly 1 tuple in the result.
- c) There are exactly n tuples in the result.
- d) It is possible that $n > 1000$ and the result has 0 tuples.
- e) It is possible that $n > 1$ and the result has 1 tuple.

For the next ten (10) questions (11 to 20) let us consider the relation scheme:

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

with the set of functional dependencies:

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

Question 11. Which of the following functional dependencies is in F^+ ?

- a) $\{A\} \rightarrow \{B, C\}$
- b) $\{B\} \rightarrow \{C, D\}$
- c) $\{D\} \rightarrow \{D\}$
- d) All of the above
- e) None of the above

Question 12. Which of the following functional dependencies is in F^+ and is completely non trivial?

- a) $\{A, B\} \rightarrow \{B, C\}$
- b) $\{B\} \rightarrow \{C, D\}$
- c) $\{D\} \rightarrow \{D\}$
- d) $\{D, B\} \rightarrow \{C\}$
- e) $\{D, B\} \rightarrow \{A, B, C, D\}$

Question 13. Which of the following functional dependencies can be derived from F using augmentation only?

- a) $\{A, B\} \rightarrow \{B, C\}$
- b) $\{A, B, C\} \rightarrow \{C, D\}$,
- c) $\{B, D\} \rightarrow \{A, B, E\}$
- d) All of the above
- e) None of the above

Question 14. Which of the following sets of attributes is a superkey?

- a) $\{A, B\}$
- b) $\{A, B, C\}$
- c) $\{A, B, C, D\}$
- d) All of the above
- e) None of the above

Question 15. Which of the following sets of attributes is a candidate key?

- a) $\{A, B\}$
- b) $\{A, B, C\}$
- c) $\{A, B, C, D\}$
- d) All of the above
- e) None of the above

Question 16. Which of the following attributes is not a prime attribute?

- a) A
- b) B
- c) C
- d) D
- e) All of the above (none of the above is a prime attribute)

Question 17. How many candidate keys are there?

- a) 1
- b) 2
- c) 3
- d) 4
- e) 5

Question 18. Which of the following is a minimal cover of F?

- a) $\{ \{A, B\} \rightarrow \{B, C\}, \{A, B\} \rightarrow \{D\}, \{D\} \rightarrow \{A, E\} \}$
- b) $\{ \{A\} \rightarrow \{B\}, \{A, B\} \rightarrow \{C\}, \{A, B\} \rightarrow \{D\}, \{D\} \rightarrow \{A\}, \{D\} \rightarrow \{E\} \}$
- c) $\{ \{A, B\} \rightarrow \{C\}, \{A, B\} \rightarrow \{D\}, \{D\} \rightarrow \{A\}, \{D\} \rightarrow \{E\} \}$
- d) $\{ \{A, B\} \rightarrow \{B\}, \{A, B\} \rightarrow \{C\}, \{A, B\} \rightarrow \{D\}, \{D\} \rightarrow \{A\}, \{D\} \rightarrow \{E\} \}$
- e) $\{ \{A, B\} \rightarrow \{C\}, \{A, B\} \rightarrow \{D\}, \{D\} \rightarrow \{A\}, \{A, B\} \rightarrow \{E\} \}$

Question 19. Which of the following statements is true about R with F?

- a) R with F is in BCNF
- b) R with F is in 3NF
- c) R with F is in 2NF
- d) All of the above
- e) None of the above

Question 20. Which of the following decomposition of R with F is lossless and dependency preserving?

- a) $R_1 = \{ \{A, B, C\}, R_2 = \{A, B, D\}, R_3 = \{A, B, E\} \}$
- b) $R_1 = \{ \{A, B, C\}, R_2 = \{D, B, E\} \}$
- c) $R_1 = \{ \{A, B, C\}, R_2 = \{D, B, E\}, R_3 = \{A, D\} \}$
- d) All of the above
- e) None of the above

Exercise II. (30 marks) Consider and use the corresponding following self-descriptive relational schema. There are four relations in the schema.

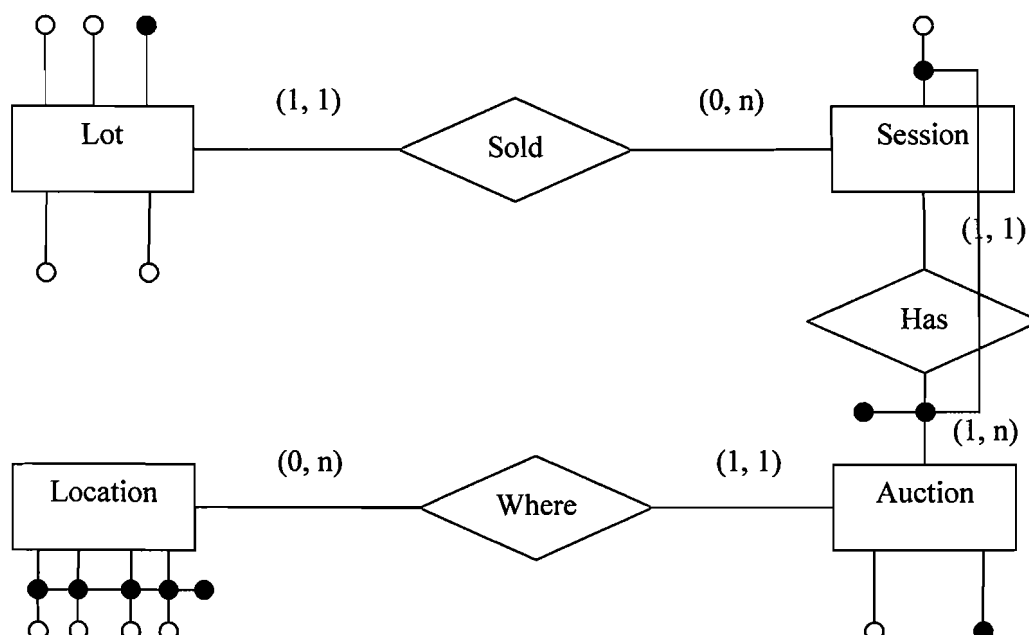
```
CREATE TABLE location (
    street    VARCHAR(8) ,
    city      VARCHAR(16) ,
    zip       NUMERIC,
    country   CHAR(2) ,
    PRIMARY KEY (street, city, zip, country))

CREATE TABLE auction (
    number    VARCHAR(16) PRIMARY KEY,
    day       DATE NOT NULL,
    street    VARCHAR(8) NOT NULL,
    city      VARCHAR(16) NOT NULL,
    zip       NUMERIC NOT NULL,
    country   CHAR(2) NOT NULL,
    FOREIGN KEY (street, city, zip, country) REFERENCES location (street, city, zip, country))

CREATE TABLE session (
    number    NUMERIC REFERENCES auction (number),
    auction   VARCHAR(16) ,
    PRIMARY KEY (auction, number))

CREATE TABLE lot (
    number    NUMERIC PRIMARY KEY,
    artist    VARCHAR(16) NOT NULL
    born      DATE NOT NULL,
    dead      DATE, % null value is used if the artist still lives
    name      VARCHAR(128) NOT NULL,
    price     NUMERIC NOT NULL
    session   NUMERIC NOT NULL,
    auction   VARCHAR(16) NOT NULL,
    FOREIGN KEY (auction, session) REFERENCES session (auction, number))
```

For your reference: the database contains information about the objects (referred to as "lots") that the company has successfully sold at auctions. Each auction has a unique number given by the company. It takes place in one location. Locations are auction rooms and are reused for several auctions. We record them separately. Some rooms may be recorded that have not yet been used. An auction may have one or more sessions. The first session is referred to as session 1, the second as session 2 etc. In each session lots are auctioned and possibly sold (note that sometimes the auction is unsuccessful and no lots are sold). If the same object is re-auctioned then it will have a different lot number. We are only interested in recording information about lots that are sold. Each lot sold has a unique lot number. Lots were sold at the prices stated. The SQL DDL code above was obtained from the entity-relationship diagram sketched below.



For the next 10 (ten) questions (21 to 30) translate the query into the language indicated. Each question is worth 3 marks.

Question 21. (SQL) Find the different living artists that have been auctioned.

Question 22. (SQL) Find the different artists who have been auctioned and the countries in which their art has been auctioned.

Question 23. (SQL) For each artist find the most expensive of his lots that has been sold. Print the artist, the lot number and the price. Do not use aggregates.

The following three (3) questions have the same query in English.

Question 24. (SQL) Find the different zip codes of locations in Singapore in which auctions have been held (do not use nested queries or aggregates).

Question 25. (TRC) Find the different zip codes of locations in Singapore in which auctions have been held.

Question 26. (Algebra) Find the different zip codes of locations in Singapore in which auctions have been held.

The following four (4) questions have the same query in English.

Question 27. (TRC) Find the different countries in which auctions have never been held.

Question 28. (SQL) Find the different countries in which auctions have never been held. Use NOT EXISTS.

Question 29. (Algebra) Find the different countries in which auctions have never been held.

Question 30. (SQL) Find the different countries in which auctions have never been held. Use algebra in SQL.

Exercise III. (30 marks) Let us consider the self-descriptive relation schema $\text{Timetable} = \{\text{Module, Lecturer, Room, Day, Time, Student, Hall}\}$ which we shall write $\text{TT} = \{\text{M, L, R, D, T, S, H}\}$

Each module has one weekly lecture. All weekly lectures for one module are taught on the same day and at the time by the same lecturer in the same room. Note that a lecturer cannot teach several lectures at the same time. A room cannot be used for several lectures at the same time. A student cannot read several lectures at the same time. Each student stays in a hall of residence.

For example:

Module	Lecturer	Room	Day	Time	Student	Hall
CS2102	Prof. Goh	COM1-126	Monday	10-12	U12345C	Temasek
CS2102	Prof. Goh	COM1-126	Monday	10-12	U03245A	Temasek
CS2102	Prof. Goh	COM1-126	Monday	10-12	U24563B	Eussof
CS2102	Prof. Goh	COM1-126	Monday	10-12	U24258E	Eussof
CS1231	Prof. Tan	COM1-126	Tuesday	9-11	NT1234H	Temasek
CS1231	Prof. Tan	COM1-126	Tuesday	9-11	U12345C	Temasek
CS1231	Prof. Tan	COM1-126	Tuesday	9-11	U00273X	Eussof
CS3223	A/P Yu	COM1-222	Monday	10-12	U00273X	Eussof
CS3223	A/P Yu	COM1-222	Monday	10-12	U22222Z	Raffles
CS3223	A/P Yu	COM1-222	Monday	10-12	NT1234H	Temasek

Question 31. (8 marks) Find a set F of functional dependencies that hold on TT . You may try and find a minimal cover (see the next question). Do not show the steps.

Question 32. (± 4 marks) If you think that your answer above is a minimal cover tick the box and you will get 4 marks. If you tick the box wrongly, you will be discounted 4 marks).

My answer is a minimal cover ☐

Question 33. (4 marks) Find the candidate keys of TT with F . Do not show the steps.

Question 34 (10 marks) Decompose TT into BCNF. Show the steps clearly. At each stage give the projected functional dependencies and the keys of the fragments.

Explain in English from left to right and top to bottom. Do not draw any kind of diagram! You may however number the steps of your explanation. Use the top spaces below to write the steps and to repeat the final result (the decomposition) separately.

The steps of the decomposition are:

The final decomposition is:

Question 35. (4 marks) If the decomposition above is not dependency preserving give one lost dependency.

-- END OF PAPER --