CS2102: Database Systems (AY2021-2022 – Sem 1)

Final Exam

Instructions

1. Please read **ALL** instructions carefully.
2. This assessment contains **16** questions (*and 1 bonus question*):
   (a) There are 10 Multiple Response Questions (MRQ): 1.1 - 1.5, 2.1 - 2.5
   (b) There is 1 Short Essay Question: 2.6
   (c) There is 1 Multiple Choice Question (MCQ): 2.7
   (d) There is 1 Hot Spot Question: 3.1 (*5 questions on Examplify*)
   (e) There are 3 Fill in the Blank Questions (FITB): 4.1, 5.1 - 5.2
3. All the assessment is be done using Examplify:
   (a) This is a secure assessment:
      i. Your Internet connection will be blocked.
      ii. You will not be able to access any other software besides Examplify.
   (b) This is a closed-book exam
4. Use the question number shown on Examplify when asking question.
   - If the answer is clear from the question pdf/Examplify, we will reply with "No Comment".
5. No additional time will be given to submit.
6. Failure to follow each of the instructions above may result in deduction of your marks.

Good Luck!

Bonus

You will only get this bonus mark if you have less than 40 marks.

0.1 Revision Time (1 mark). Consider the following topics:

1. Relational Algebra
2. Entity-Relationship
3. Armstrong's Axioms
4. Closure
5. Minimal Basis
6. BCNF
7. 3NF
8. Lossless Join
9. Dependency Preserving

Which of the above are **NOT** tested in this exam? Write the number on Examplify after reading all the questions below.

1 Functional Dependencies

In this section, we consider the schema `R(A, B, C, D, E)` with the following set of functional dependencies:

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

1.1 Closure (2 marks). Select **ALL** the attributes in the closure of $\{\texttt{A,E}\}$ (*i.e.,* $\{\texttt{A,E}\}^+$) with respect to `F`.

(A) `A` (B) `B` (C) `C` (D) `D` (E) `E`

1.2 Implied FD (2 marks). functional dependencies that are implied by `F` (*i.e.,* can be derived from `F`) from the choices below. If none of the choices can be implied, you should choose "None of the above".

(A) $\{\texttt{A}\} \to \{\texttt{D}\}$ (*this was* $\{A\} \to \{B\}$ in Examplify but it is still can be derived)

(B) $\{\texttt{D,E}\} \to \{\texttt{A}\}$

(C) $\{\texttt{C,D}\} \to \{\texttt{E}\}$

(D) $\{\texttt{A,D}\} \to \{\texttt{C}\}$

(E) None of the above

1.3 Superkeys (2 marks). Select **ALL** the superkeys of `R` with respect to `F` from the choices below. If none of the choices is a superkey, you should choose "None of the above".

(A) $\{\texttt{A,B,C}\}$

(B) $\{\texttt{B,C,D}\}$

(C) $\{\texttt{C,D,E}\}$

(D) $\{\texttt{A,B,E}\}$

(E) None of the above

1.4 Prime Attributes (2 marks). Select **ALL** prime attributes of `R` with respect to `F`.

(A) `A` (B) `B` (C) `C` (D) `D` (E) `E`

1.5 Functional Equivalence (2 marks). We say that two attributes `X` and `Y` are *functionally equivalent* if and only if we can show both: $\{\texttt{X}\} \rightarrow \{\texttt{Y}\}$ and $\{\texttt{Y}\} \rightarrow \{\texttt{X}\}$. Select **ALL** attributes that are functionally equivalent to `B` with respect to `F`. For ***obvious*** reason, your answer should include `B`.

(A) `A` (B) `B` (C) `C` (D) `D` (E) `E`

2 Normal Forms

In this section, we consider the same schema as before R(A, B, C, D, E) with the same set of functional dependencies as before:

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

We further consider the following decomposition for R:

$$\{\ R1(A,B,C),\ R2(A,C,D),\ R3(A,C,E),\ R4(B,D,E)\ \}$$

2.1 Properties (2 marks). Note that R is **NOT** in BCNF. Select **ALL** the functional dependencies below that violates the BCNF property of R with respect to F. In other words, the functional dependencies must also be implied by F. If none of the choices is a violation that is implied by F, you should choose "None of the above".

(A) $\{A,E\} \rightarrow \{B\}$

(B) $\{A,B,D\} \rightarrow \{C\}$

(C) $\{A,D,E\} \rightarrow \{B\}$

(D) $\{A,C\} \rightarrow \{E\}$

(E) None of the above

2.2 BCNF (2 marks). Select **ALL** the decomposed schema that are in BCNF with respect to F. If none of the choices is in BCNF, you should choose "None of the above".

(A) R1 (B) R2 (C) R3 (D) R4 (E) None of the above

2.3 3NF (2 marks). Select **ALL** the decomposed schema that are **NOT** in 3NF with respect to F. If all of the choices are in 3NF, you should choose "None of the above".

(A) R1 (B) R2 (C) R3 (D) R4 (E) None of the above

2.4 Lossless Join (2 marks). Select **ALL** the lossless join decomposition of R with respect to F. If none of the choices is a lossless join decomposition, you should choose "None of the above". Note that you do not have to take into account any other properties beside lossless join decomposition.

(A) { R1(A,B), R2(B,C,D), R3(A,E) }

(B) { R1(A,B,D,E), R2(A,C,E), R3(B,C) }

(C) { R1(A,B,C), R2(A,C,D,E) }

(D) { R1(A,B,E), R2(A,C,D) }

(E) None of the above

2.5 Dependency Preserving (2 marks). Select **ALL** the dependency preserving decomposition of `R` with respect to `F`. If none of the choices is a dependency preserving decomposition, you should choose "None of the above". Note that you do not have to take into account any other properties beside dependency preserving decomposition.

(A) { `R1(A,B), R2(B,C,D), R3(A,E)` }

(B) { `R1(A,B,D,E), R2(A,C,E), R3(B,C)` }

(C) { `R1(A,B,C), R2(A,C,D,E)` }

(D) { `R1(A,B,E), R2(A,C,D)` }

(E) None of the above

2.6 Optimal Decomposition (3 marks). Find a lossless join and dependency preserving BCNF decomposition of `R` with respect to `F` *if it exists*. Otherwise, find a lossless join and dependency preserving 3NF decomposition of `R` with respect to `F`.

Furthermore, your answer should not contain any **redundant schema**. We say that a schema `Ri` in a decomposition is redundant if and only if there is another schema `Rj` in the decomposition such that all attributes in `Ri` exists in `Rj`. For instance, `R1(A,B,C)` is redundant if there is `R2(A,B,C,D)`.

Your answer should be in the same syntax as Assignment 2 (*relevant example reproduced below*). Any deviation from the syntax may be penalised.

`{R1(A, B, C), R2(D, E, F)}`

Note that whitespaces are ignored and may be omitted for simplicity. However, brackets are important and the correct use of brackets as well as the correct type of brackets are expected.

Do **NOT** any working and/or other texts besides the answer in the correct format. Otherwise, additional penalty may be applied.

Your answer:

2.7 With Complete Information (1 mark). Is your answer in the previous question BCNF or 3NF? Note, you will get this mark even if your answer for the previous question is wrong as long as you correctly choose the appropriate answer. However, if you do not have any answer for the previous question, you will not get any mark for this one.

(A) `BCNF`

(B) `3NF`

3 Database Modeling with ER Diagrams

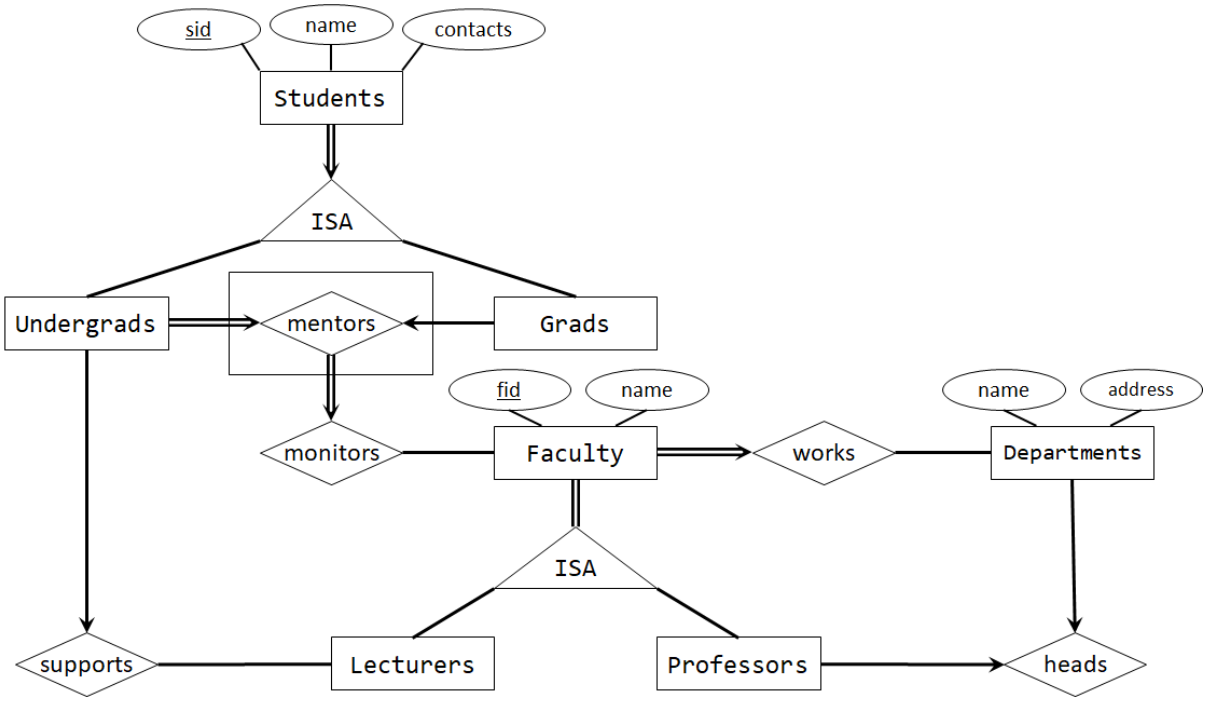
3.1 ER Diagram Errors (5 marks). The ER diagram shown below represents a simplified university database and contains **at most 5 errors**. An error may be due to the use of incorrect notations or due to incorrectly modeling the following constraints:

- Each students must be either an Undergrad or Grad student but not both; each student has a name, a set of contact numbers, and is uniquely identified by an id (*sid*).
- A faculty member may be a Lecturer or Professor; each faulty member has a name and is uniquely identified by an id (fid).
- Each faculty member works for exactly one department; each department has an address and is uniquely identified by its name.
- Each Undergrad student is mentored by a Grad student but some Grad student may decide not to mentor any Undergrad student. If they do mentor, they can only mentor one Undergrad.
- Each Undergrad-Grad mentorship is monitored by a faculty member.
- Each department must be headed by exactly one professor; a professor can only be a head to at most one department.
- An Undergrad student might receive additional support from a Lecturer.

In the following 5 questions on Examplify, you will be presented with the following ER diagram (*on the next page*). In each question, place a pin over 1 of the 5 errors. Note the order in which you find and pin the 5 errors does not matter. If there are **fewer than 5 errors**, you should leave it *blank* instead of answering with duplicate errors (*i.e.,* the same error used before). You should place your pin according to the following rule:

- If the mistake is due to attribute, your pin should be at the center of the oval.
- If the mistake is due to entity set, your pin should be at the center of the rectangle.
- If the mistake is due to relationship set or aggregate, your pin should be at the center of the diamond.
- If the mistake is such that the ISA hierarchy is not supposed to be used, your pin should be at the center of the the triangle. However, if the mistake is due to the overlap and/or covering constraints, your pin should be on the line.
- If the mistake is due to the connection (*i.e., lines/arrows*), your pin should be on the line (if possible, outside of any rectangle unless the mistake is due to aggregate).

ER diagram:



4 Cardinalities

4.1 Cardinalities of RA operations (5 Marks). You are given 2 relations R and S, with m being the number of tuples in R (i.e., $|R| = m$) and n being the number of tuples in S (i.e., $|S| = n$). Assume that $m > n > 0$, R and S are union-compatible and both relations do not contain any *null* values.

Fill in the blank below with the minimum and maximum number of tuples in the resulting relation. Specifies the minimum and maximum number of tuples in the result relation – denoted as tuples [*minimum*, *maximum*] to mean that the result is *inclusive* of both *minimum* and *maximum*. There are no other assumption on the schema of R and S!

Please use the following expressions for your answer:

- Values: 0, 1, 2, ...
- Variables: m or n
- Operations:
  - Addition: $m + n$ or $n + m$
  - Subtraction: $m - n$ or $n - m$
  - Multiplication: mn or nm
  - Division: m/n or n/m

You should not use any other expressions for your answer.

(a) $R \cup S$: [____ , ____]

(b) $R \cap S$: [____ , ____]

(c) $R - S$: [☐ , ☐]

(d) $R \bowtie S$: [☐ , ☐]

(e) $R \rtimes S$: [☐ , ☐]

5 Theory

In this section, your answer should follow the same syntax as Assignment 2 (*examples reproduced below*). Any deviation from the syntax may be penalised.

- Schema: `R(A, B, C, D, E)`
- Functional Dependency: `{A,B} -> {C,D}`
- Set of Schema: `{R1(A, B, C), R2(D, E, F)}`
  - The name of the schema is irrelevant but must be written.
- Set of Functional Dependency: `{ {A,B} -> {C,D}, {E,G} -> {H,I} }`

Note that whitespaces are ignored and may be omitted for simplicity. However, brackets and arrows are important and the correct use of brackets as well as the correct type of brackets are expected.

5.1 Keys and Equivalence (3 marks). Consider any schema `R` with an arbitrary set of functional dependencies `F1` and `F2`. Bob claimed that if the key of `R` with respect to `F1` is *the same as* the key of `R` with respect to `F2`, it means that `F1` is *equivalent* to `F2`.

Alice says that it is not. Using as few attributes as possible and as few functional dependencies as possible provide a counter-example to Bob's claim. In other words, provide the concrete example of `R`, `F1` and `F2` to counter Bob's claim.

Do **NOT** any working and/or other texts besides the answer in the correct format. Otherwise, additional penalty may be applied.

- Answer for `R`:
- `F1` =
- `F2` =

5.2 Minimal Basis (3 marks). Consider an arbitrary set of functional dependencies `F` such that `F` contains only non-trivial and decomposed functional dependencies. Alice claims that *any* minimal basis `Fb` of `F` must share **at least one** functional dependencies with `F`. In other words, the intersection of `F` and `Fb` must have at least one element (*i.e.,* $\texttt{F} \cap \texttt{Fb} \neq \emptyset$).

Now Bob says that it is, in fact, not. Using as few attributes as possible and as few functional dependencies as possible provide a counter-example to Alice's claim. In other words, provide the concrete example of `F` and `Fb` to counter Alice's claim.

Do **NOT** any working and/or other texts besides the answer in the correct format. Otherwise, additional penalty may be applied.

- `F` =
- `Fb` =