Name: ________________________________

GT account (gtg, gth, msmith3, etc): ___________________________ Section (e.g., B1): _______

Signature: ________________________________

- Failure to properly fill in the information on this page will result in a deduction of up to 4 points from your exam score.
- Signing signifies that you agree to comply with the Academic Honor Code of Georgia Tech.
- Calculators and cell phones are NOT allowed.

Completely fill in the box corresponding to your answer choice for each question.

1. [ ] [A] [B] [C] [D]
2. [ ] [A] [B] [C] [D]
3. [ ] [A] [B] [C] [D]
4. [ ] [A] [B] [C] [D]
5. [ ] [A] [B] [C] [D]
6. [ ] [A] [B] [C] [D]
7. [ ] [A] [B] [C] [D]
8. [ ] [A] [B] [C] [D]
9. [ ] [A] [B] [C] [D]
10. [ ] [A] [B] [C] [D]
11. [ ] [A] [B] [C] [D]
12. [ ] [A] [B] [C] [D]
13. [ ] [A] [B] [C] [D]
14. [ ] [A] [B] [C] [D]
15. [ ] [A] [B] [C] [D]
16. [ ] [A] [B] [C] [D]
17. [ ] [A] [B] [C] [D]
18. [ ] [A] [B] [C] [D]
19. [ ] [A] [B] [C] [D]
20. [ ] [A] [B] [C] [D]
21. [ ] [A] [B] [C] [D]
22. [ ] [A] [B] [C] [D]
23. [ ] [A] [B] [C] [D]
24. [ ] [A] [B] [C] [D]
25. [ ] [A] [B] [C] [D]

Number missed: ______ Final Score: ______
Student(\text{SID}, \text{Sname}, \text{GPA})

Department(\text{DName}, \text{Chair}, \text{Building}, \text{Room})

Course(\text{DName}, \text{CID}, \text{CName}, \text{Hours})

Enrolled(\text{DName}, \text{CID}, \text{SID})

- \text{DName} is a foreign key in Course referencing the Department relation
- \text{DName},\text{CID} is a foreign key in Enrolled referencing the Course relation
- \text{SID} is a foreign key in Enrolled referencing the Student relation
- Primary keys are underlined

\begin{tabular}{|c|c|c|}
\hline
\text{SID} & \text{Sname} & \text{GPA} \\
\hline
11 & Bush & 3.0 \\
12 & Cruz & 3.2 \\
13 & Clinton & 3.9 \\
22 & Sanders & 3.0 \\
33 & Trump & 3.8 \\
\hline
\end{tabular}

\begin{tabular}{|c|c|c|}
\hline
\text{DName} & \text{CID} & \text{SID} \\
\hline
CS & 101 & 11 \\
Math & 101 & 11 \\
CS & 101 & 12 \\
CS & 101 & 22 \\
Math & 103 & 33 \\
EE & 102 & 33 \\
CS & 102 & 22 \\
\hline
\end{tabular}

\begin{tabular}{|c|c|c|c|c|}
\hline
\text{DName} & \text{Chair} & \text{Building} & \text{Room} \\
\hline
CS & Rubio & Ajax & 100 \\
Math & Carson & Acme & 300 \\
EE & Kasich & Ajax & 200 \\
Music & Costello & North & 100 \\
\hline
\end{tabular}

\begin{tabular}{|c|c|c|c|}
\hline
\text{DName} & \text{CID} & \text{CName} & \text{Hours} \\
\hline
CS & 101 & Programming & 4 \\
CS & 102 & Algorithms & 3 \\
Math & 101 & Algebra & 3 \\
Math & 103 & Calculus & 4 \\
Music & 104 & Jazz & 3 \\
EE & 102 & Circuits & 3 \\
\hline
\end{tabular}

Figure 1: Relational Database Schema
1. Which of the following statements is true with regard to the relational data model?
   A. A domain for an attribute is a set of atomic values.
   B. Several attributes in one relation schema may have the same domain.
   C. A tuple in a relation consists of one value from each attribute domain of that relation. The value may possibly be a Null value.
   D. All of the above

2. Which of the following is the mathematical definition of a relation, \( r(R) \), of degree \( n \)?
   A. \( r(R) \subseteq \text{dom}(A_1) \times \text{dom}(A_2) \times \ldots \times \text{dom}(A_n) \)
   B. \( r(R) \subseteq \text{dom}(A_1) \cap \text{dom}(A_2) \cap \ldots \cap \text{dom}(A_n) \)
   C. \( r(R) \subseteq \text{dom}(A_1) \cup \text{dom}(A_2) \cup \ldots \cup \text{dom}(A_n) \)
   D. none of the above

3. Which of the following is the reason why the ordering of tuples in a relation is not part of the relational data model?
   A. A relation has only one primary key hence tuples must appear in order of their primary key values.
   B. Mathematically, elements in a set have no order among them, hence the set of tuples for a relation has no particular order.
   C. The relational data model represents facts at a logical level not a physical level.
   D. B and C together

4. Which of the following is true about a superkey?
   A. It specifies a uniqueness constraint that no two tuples in any state of a relation can have the same value for the superkey
   B. Every relation has at least one superkey
   C. A key is a superkey
   D. All of the above

5. Which of the following is true about any relation schema with 3 candidate keys?
   A. The relation schema has 3 primary keys.
   B. The relation schema has no more than 3 superkeys.
   C. The relation schema must have exactly 3 attributes.
   D. None of the above

6. Is a relational database schema the same as a relational database state?
   A. Yes
   B. No

7. If an update operation changes the value of the primary key of any relation to NULL, then that update would always violate which of the following constraints for the relation?
   A. referential integrity constraint
   B. entity integrity constraint
   C. both A and B
   D. tuple cardinality constraint
Refer to Figure 1 for questions 8 through 25.

8. Which of the following statements about the Course relation is false?
   A. The Course relation consists of a set of 4-tuples.
   B. It is not allowable to change the DName attribute to a Null value for any row.
   C. There are 4 superkeys for the Course relation.
   D. It is allowable to change the CID value to a Null value in the last row.

9. The Enrolled relation has how many candidate keys?
   A. 0
   B. 1
   C. 3
   D. 6

10. The deletion of the first row in the Department relation causes an integrity violation for which of the relations?
    A. Department
    B. Course
    C. Enrolled
    D. Both Course and Enrolled

11. If the last row in the Course relation is deleted and if a cascading of deletes is in effect for all relations, then which relation will have at least one tuple deleted from it?
    A. only Course
    B. Course, Enrolled and Student
    C. Course and Enrolled
    D. Course and Department

12. Inserting the tuple <'CS', 103, 33> into the Enrolled relation will cause which of the following?
    A. A foreign key violation
    B. A primary key violation
    C. Both A and B
    D. None of the above

13. How many tuples will be returned by the following relational algebra query?

\[ \pi_{CID, DName}(\sigma_{DName='CS'}(Enrolled)) \]

   A. 4
   B. 3
   C. 2
   D. 1
14. How many tuples appear in the result of the following query?

\[ \pi_{\text{DName}}(\text{Department}) - \pi_{\text{DName}}(\text{Enrolled}) \]

A. 3  
B. 2  
C. 1  
D. 0

15. How many more tuples appear in the Cartesian product of Enrolled and Course versus the natural join of Enrolled and Course?

A. 6  
B. 7  
C. 35  
D. 42

16. Which of the following queries returns the name of a student, if that student is enrolled in 2 or more courses?

A. \( \pi_{\text{SName}}(\sigma_{\text{GPA} > 3.0}(\text{Student}) \ast \sigma_{\text{DName} = 'CS'}(\text{Enrolled}) \ast \text{Student}) \)
B. \( \pi_{\text{SName}}(\text{Enrolled} \ast \text{Student}) \)
C. \( \pi_{\text{SName}, \text{SID}}(\text{Student} \div \pi_{\text{SID}}(\text{Enrolled})) \)
D. None of the above

17. What is the result of the following relational algebra query?

\[ \pi_{\text{SName}}(\sigma_{\text{GPA} > G}(\rho_{\text{G}}(\pi_{\text{GPA}}(\text{Student}) \times \text{Student}))) \]

A. Clinton  
B. Cruz  
C. Trump  
D. Sanders  
E. Costello

18. Which relational algebra query returns the SName of each student that has a GPA > 3.0 and is enrolled in at least 1 course in the CS department?

A. \( \pi_{\text{SName}}(\sigma_{\text{GPA} > 3.0}(\text{Student}) \ast \sigma_{\text{DName} = 'CS'}(\text{Enrolled})) \)
B. \( \pi_{\text{SName}}(\sigma_{\text{GPA} > 3.0 \text{ AND DName} = 'CS'}(\text{Student} \ast \text{Enrolled})) \)
C. \( \pi_{\text{SName}, \text{SID}}(\sigma_{\text{GPA} > 3.0}(\text{Student}) \ast \pi_{\text{SID}}(\sigma_{\text{DName} = 'CS'}(\text{Enrolled}))) \)
D. All of the above

19. Does the following query return the lowest GPA of any student?

\[ \pi_{\text{GPA}}(\text{Student}) - \pi_{\text{GPA}}(\sigma_{\text{GPA} > G}(\text{Student} \times \rho_{\text{G}}(\pi_{\text{GPA}}(\text{Student})))) \]

A. Yes  
B. No
20. Which of the following relational algebra queries would return course information for courses that are listed for less than 2 hours or more than 5 hours?

A. \( \sigma_{\text{Hours}<2 \text{ AND } \text{Hours}>5} (\text{Course}) \)
B. \( \sigma_{\text{Hours}<2} (\text{Course}) \ast \sigma_{\text{Hours}>5} (\text{Course}) \)
C. \( \sigma_{\text{Hours}<2} (\text{Course}) \cup \sigma_{\text{Hours}>5} (\text{Course}) \)
D. All of the above

21. Which statement is true about relational algebra queries Q1 and Q2 for our current relational database state?

Q1: \( \text{Department} \bowtie\bowtie \text{Course} \)  
Q2: \( \text{Department} \bowtie\bowtie \text{Course} \)

A. Q1 returns more tuples than Q2
B. Q1 returns less tuples than Q2
C. Q1 and Q2 return the same number of tuples
D. Q1 returns tuples that include Null values for some attributes

22. Does the following query return any tuples?

\[ \sigma_{\text{DName} = '\text{Music}' \bowtie\bowtie (\text{Course}) \ast \text{Department} \ast \sigma_{\text{SID}>12} (\text{Enrolled})} \]

A. Yes
B. No

23. Would the following query return all the courses (department and number) in which no student is enrolled?

\[ \pi_{\text{Dname}, \text{CID}} (\sigma_{\text{SID}=\text{null}} (\text{Course} \bowtie\bowtie \text{Dname} = D \text{ AND } \text{CID} = C) \bowtie\bowtie \bowtie \text{Enrolled})} \]

A. Yes
B. No

24. How many tuples would the previous query return?

A. 0
B. 1
C. 2
D. 3

25. Which query would return all the courses (department and number) \textit{Bush} is enrolled in?

A. \( \pi_{\text{DName}, \text{CID}} (\sigma_{\text{Sname} = '\text{Bush}' \bowtie\bowtie (\text{Student} \ast \text{Enrolled})} \)
B. \( \pi_{\text{DName}, \text{CID}} (\sigma_{\text{Sname} = '\text{Bush}' \bowtie\bowtie (\text{Student} \bowtie\bowtie \text{SID} = ESID \bowtie\bowtie \bowtie (\text{DName, CID, ESID}) \bowtie\bowtie \bowtie \text{Enrolled})} \)
C. All of the above
D. None of the above

26. Which relational tuple calculus query produces the same result as the following relational algebra query?

\[ \pi_{\text{CID}, \text{CName}} (\sigma_{\text{Hours}>3 \text{ AND } \text{DName} = '\text{CS}' \bowtie\bowtie (\text{Course} \bowtie\bowtie \text{CID})} \)

A. \( \{t.\text{CID}, t.\text{CName}|\text{Course}(t) \text{ AND } t.\text{Hours} > 3 \text{ AND } t.\text{DName} = '\text{CS}'\} \)
B. \( \{t.\text{CID}, t.\text{CName}|\text{Course}(t)\} \)
C. \( \{t.\text{CID}, t.\text{CName}|\text{Course}(t) \text{ AND } (\exists s)(\text{Course}(s) \text{ AND } t.\text{Hours} > 3 \text{ AND } t.\text{CID} = s.\text{CID})\} \)
D. None of the above
27. What is the result of executing the following relational tuple calculus query?

\{t.Chair\mid \text{Department}(t) \land (\exists s)(\text{Enrolled}(s) \land t.DName = s.DName)\}

A. Costello
   - Rubio
   - Carson
   - Kasich
B. Kasich
   - Rubio
   - Rubio
C. Kasich
   - Rubio
   - Carson
D. None of the above

28. How many tuples appear in the result of the following relational tuple calculus query?

\{t\mid \text{Department}(t) \land (\exists s)(\text{Student}(s))\}

A. 28
B. 7
C. 4
D. 0