

Bilkent University

Department of Computer Engineering

CS281
Computers and Data Organization

Spring 2026

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Midterm Examination

March 29, 2026

Duration: 113 Minutes

Number of Questions to be Answered: 5

Student Name and Last Name: _____

Student ID: _____

Student Signature: _____

Rules and Directions:

1. There are 6 questions on exam sheets. You may select up to 5 and attempt to answer them. If you answer more than 5 questions, only the first 5 (in numerical order) will be evaluated.
 2. You choose a question by writing your responses beneath the corresponding question.
 3. Each question is worth 20 points. Partial points may be awarded if any part of the answer is correct.
 4. The maximum time to complete the exam is 113 minutes, with no extensions under normal circumstances.
 5. During the exam, you may use printed copies of the course slides and your own handwritten notes. No other printed materials are permitted.
 6. You are not permitted to use any electronic devices such as iPhones, smartphones, tablets, iPads, smartwatches, laptops, or MacBooks. You must switch off all applicable devices and hand them over to the exam proctors.
 7. You are not allowed to ask questions or request clarifications during the exam. Answer based on your understanding of the questions as presented. If you make any assumptions, be sure to record them appropriately.
 8. Any attempt at cheating will result in your exam paper being marked, and you may receive a score of 0 for the exam.
 9. Remember, it is far more honorable to fail than to cheat.
 10. You may leave the exam room at any time, but once you exit, you cannot return.
 11. Be respectful of your fellow students by not causing any disturbances, allowing them to focus.
 12. Please write clearly and legibly. If your handwriting is difficult to read, you may lose points for the corresponding questions.
 13. Write your student ID and sign each page of the exam.
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I have read, understood, and concurred with all the rules and directions.

Student ID: _____

Sign: _____

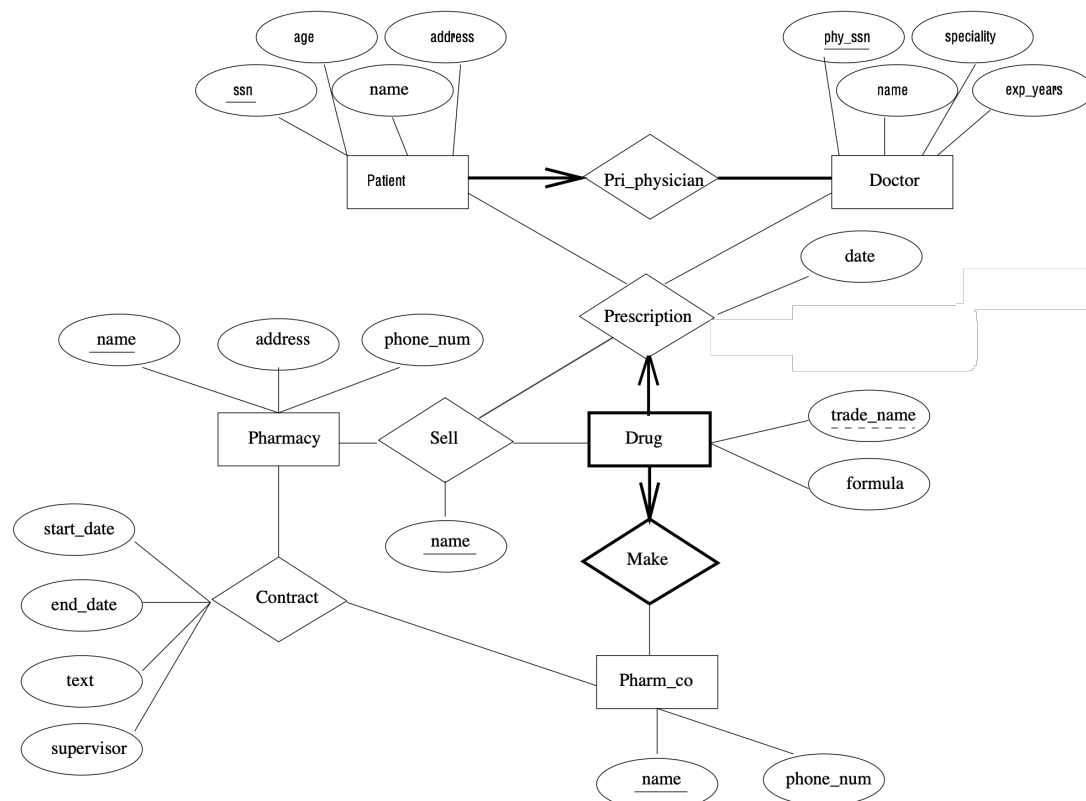
Student ID: _____ Sign: _____

1. Define the concept of ***data independence*** and explain how it is achieved through the ***levels of abstraction*** in a DBMS. (20 points)
An ideal answer shall include at least 13 well-developed sentences.

2. Simulate:

The Bilko chain of pharmacies has offered to give you a free lifetime supply of medicine if you design its database. Given the rising cost of health care, you agree. Here's the information that you gather: Patients are identified by an IBAN, and their names, addresses, and ages must be recorded. Doctors are identified by an SSN. For each doctor, the name, specialty, minor, and years of experience must be recorded. Each pharmaceutical company is identified by name and has a phone number. For each drug, the trade name and formula must be recorded. Each drug is sold by a given pharmaceutical company, and the trade name identifies a drug uniquely from among the products of that company. If a pharmaceutical company is deleted, you need not keep track of its products any longer. Each pharmacy has a name, address, and phone number. Not every patient has a primary physician. Every doctor has at least one patient. Each pharmacy sells several drugs and has a price for each. A drug could be sold at several pharmacies, and the price could vary from one pharmacy to another. Doctors prescribe drugs for patients. A doctor could prescribe one or more drugs for several patients, and a patient could obtain prescriptions from several doctors. Each prescription has a date and a quantity associated with it. You can assume that, if a doctor prescribes the same drug for the same patient more than once, only the last such prescription needs to be stored. Pharmaceutical companies have long-term contracts with pharmacies. A pharmaceutical company can contract with several pharmacies, and a pharmacy cannot contract with several pharmaceutical companies. For each contract, you must store a start date, an end date, and the text of the contract. Pharmacies appoint a supervisor for each contract. There must always be a supervisor for each contract, but the contract supervisor can change over the lifetime of the contract.

Assume that you had asked your favorite LLM tool to draw the ER diagram for the database, and it initially created the following depiction. **Identify** (clearly indicate) and **justify** (explain the reasons for) any problems, if present, in the drawing. (20 points)



3. Assume that in a stimulating manufacturing system, you are tasked to model a ternary relationship ASSIGNMENT among certain entity sets Machine, Operator, and Shift. By design, each Machine must be assigned to exactly one Operator-Shift combination (i.e., Machine has requirements of total participation and a key constraint in the relationship). Additionally, each Operator can be assigned to at most one Machine-Shift combination at a time (i.e., Operator has a key constraint). There are no other constraints.

Each entity set has the following attributes:

- Machine: (*machine_id*, *type*) where *machine_id* is the key
- Operator: (*operator_id*, *name*) where *operator_id* is the key
- Shift: (*shift_id*, *time_slot*) where *shift_id* is the key

The relationship ASSIGNMENT has no descriptive attributes.

To construct SQL statements that enforce the given constraints, assume that the Bilko LLM was used to generate the following statements. However, since the Bilko LLM may occasionally produce incorrect or hallucinated outputs, you want to carefully review its results. Identify and correct any errors, if any, in the SQL statements below. (20 points)

Write the total number of found and fixed problems:

```
CREATE TABLE Operator (  
    operator_id CHAR(13),  
    name CHAR(113),  
    UBER KEY (operator_id))
```

```
CREATE TABLE Shift (  
    shift_id CHAR(13),  
    time_slot CHAR(27),  
    PRIMARY KEY (machine_id))
```

```
CREATE TABLE Assignment (  
    machine_id CHAR(13),  
    type CHAR(27),  
    operator_id CHAR(13),  
    shift_id CHAR(13),  
    PRIMARY KEY (MD),  
    NOT UNIQUE (operator_id),  
    FRIENDS KEY (operator_id) REFERENCES Shift(operator_id),  
    FOE KEY (shift_id) VIOLATES Operator(shift_id))
```

4. Kindly provide responses to the following sub-questions. For parts b and c, if you need, you may refer to the *schema diagram for the COMPANY relational database schema* given in Question 5.

- a. Assume that you have recently graduated from Bilko and started working at your dream company as a motivated and high-potential contributor. During a meeting, a senior colleague (who has been with the company for over thirty-five years and believes they know best) argues that “*Studying relational calculus is a waste of time; for a database professional, knowing relational algebra alone is sufficient.*” How would you respond to this claim? Do you agree or disagree? Justify your position with two real-life examples. (7 points)
An ideal answer shall include at least 7 well-developed sentences.

- b. Complete the following relational **algebra** expression to guarantee it meets the **Query**: *For every project located in ‘MD’, list the project number, the controlling department number, and the department manager’s last name, address, and birth date.* (7 points)

$$\pi_{\text{Pnumber, Dnum, Lname, Address, Bdate}} \left(\left(\left(\sigma_{\text{Plocation} = \text{'MD'}} (\text{PROJECT}) \right) \right) \right. \\
\left. \left. \left. \sigma_{\text{Dnum} = \text{Dnumber}} (\text{DEPARTMENT}) \right) \right) \sigma_{\text{Mgr_ssn} = \text{Ssn}} (\text{EMPLOYEE}) \right)$$

- c. Find and fix the problems (if any) in the following relational **calculus** expression based on the **Query**: *List the names of employees who work on all the projects controlled by department number 13.* (6 points)

$$\{E.Lname, E.Fname \mid \text{EMPLOYEE } E \text{ AND } ((\exists X) (\text{NOT } (\text{PROJECT } X) \text{ OR } \text{AND } (X.Dnum=13) \text{ OR } ((\forall W)(\text{WORKS_ON } W \text{ AND } W.Essn=E.Ssn \text{ AND } X.Pnumber <> W.Pno))))\}$$

Write the total number of found and fixed problems:

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5. Please provide answers to the following sub-questions. While doing so, refer to the *schema diagram for the COMPANY relational database schema* given below.

EMPLOYEE

Fname	Minit	Lname	<u>Ssn</u>	Bdate	Address	Sex	Salary	Super_ssn	Dno
-------	-------	-------	------------	-------	---------	-----	--------	-----------	-----

DEPARTMENT

Dname	<u>Dnumber</u>	Mgr_ssn	Mgr_start_date
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DEPT_LOCATIONS

<u>Dnumber</u>	<u>Dlocation</u>
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PROJECT

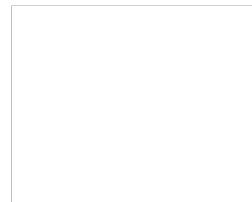
Pname	<u>Pnumber</u>	Plocation	Dnum
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WORKS_ON

<u>Essn</u>	<u>Pno</u>	Hours
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DEPENDENT

<u>Essn</u>	<u>Dependent_name</u>	Sex	Bdate	Relationship
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- a. Find and fix the problems (if any) in the following SQL statement based on the **Query**: *For each project on which more than two employees work, retrieve the project number, the project name, and the number of employees who work on the project. (10 points)*

```

SELECT    Pnumber, Pname, COUNT (*)
FROM      PROJECT, WORKS_ON
WHERE     Pnumber=Pno
GROUP BY  Pnumber, Pname
HAVING    COUNT (*) > 2

```

Write the total number of found and fixed problems:

- b. Complete the following SQL statement to guarantee it satisfactorily meets the **Query**: *For each department that has more than five employees, retrieve the department number and the number of its employees who are making more than \$40,000. (10 points)*

```

SELECT    Dnumber, _____
FROM      DEPARTMENT, EMPLOYEE
WHERE     Dnumber=Dno AND _____ AND
( SELECT  _____
  FROM    _____
  GROUP BY Dno
  HAVING  _____ )

```

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6. For each concept given below, write a three- or four-sentence explanation of a real-life example elucidating how the concept might be applied in your own field of study or professional domain (e.g., Industrial Engineering, Economics, Ele. & Electro. Eng., etc.).

Integrity Constraints (4 points)

Referential Integrity (4 points)

Query Optimizer (4 points)

$p \rightarrow q \equiv \neg p \vee q$ (4 points)

Division (4 points)

End of the exam!

*Thanks a lot for your noble efforts.
You perfectly deserved it, and you should proudly celebrate...*