Please refer to questions in slides, labs and assignments for more examples.
More details about the final exam will be given in week 12.

THE AUSTRALIAN NATIONAL UNIVERSITY

Second Semester Examination – November 2012

RELATIONAL DATABASES

(COMP2400/COMP6240)

Writing period: 3 hours duration
Study period: 15 minutes duration
Permitted materials: A4 paper (one sheet) with handwritten notes one side only

Instructions:

- This exam booklet contains 5 questions, totaling 65 marks.
- You need to answer all questions. Whenever you feel that some information is missing, add an assumption and make it explicit in your solution.
- All your answers must be written in the spaces provided in this booklet. You may be provided with scrap paper for working, but it must **not** be used to write final answers. There is additional space at the end of the booklet in case the spaces provided under questions are insufficient.
- Do not remove this booklet from the examination room.

Student Number	

Official use only:

Question	1	2	3	4	5
Mark					
Out of	17	8	15	18	7

Total: ________ /65

Question 1: SQL and the Relational Model [17 marks]

1. a General Concepts [4 marks]

1. a (i) [2 marks]

Explain the relationship of data independence with the ANSI/SPARC three level architecture.

Answer: Refer to the text book and lecture notes.

1. a (ii) [1 mark]

Which of the following statements are true for a relation?

(1) Each superkey is a candidate key.

(2) Each candidate key is a superkey.

(3) The primary key is a candidate key, but there may be a candidate key that is not a primary key.

Answer: (2) and (3)

1. a (iii) [1 mark]

Given the sets $A = \{Sue, Ali\}$, $B = \{white, black\}$ and $C = \{cat, dog\}$, what is the Cartesian product $A \times B \times C$?

Answer:

$A \times B \times C$ = {(Sue, white, cat)
(Sue, white, dog)
(Sue, black, cat)
(Sue, black, dog)
(Ali, white, cat)
(Ali, white, dog)
(Ali, black, cat)
(Ali, black, dog)}

1. b Writing SQL [4 marks]

Not relevant to the final examination this year

1. c SQL Evaluation [5 marks]

Not relevant to the final examination this year

1. d Integrity Constraints [4 marks]

1. d (i) [2 marks]

Suppose that the relation SUPERVISE was created as follows:

```
CREATE TABLE SUPERVISE (
    pssn INT REFERENCES PROFESSOR(ssn) ON DELETE NO ACTION,
    gid INT REFERENCES GRADUATE(gid) ON DELETE SET NULL,
    pid INT REFERENCES PROJECT(pid) ON DELETE CASCADE,
);
```

Which of the following statements are true, and which are false?

(a) If we delete a tuple from SUPERVISE, any tuples in PROJECT referred to by this tuple are also deleted.

(b) If we delete a tuple from GRADUATE, some tuples of SUPERVISE may have their values of attribute gid set to NULL.

(c) If we try to insert a tuple into PROFESSOR, with an ssn that does not exist in SUPERVISE, the operation is rejected.

(d) If we try to insert a tuple into SUPERVISE, with a gid that does not exist in GRADUATE, the operation is rejected.

Provide your answer in the following table.

Statements	(a)	(b)	(c)	(d)
True		√		√
False	√		√	

1. d (ii) [2 marks]

Consider the relation BOOK in Figure 1, which has the primary key $\{bid\}$ and the foreign key $[aid] \subseteq$ AUTHOR$[aid]$.

BOOK				
bid	title	language	date	aid
1	The Plague	French	1947	4
2	The Cat in the Hat	English	1957	2
3	The Hobbit	English	1937	1
4	The Lord of the Rings	English	1954	1

AUTHOR	
aid	name
1	J.R.R.Tolklen
2	Dr. Seuss
3	S.E.Hinton
4	Albert Camus

Figure 1: Relation BOOK and AUTHOR

- Write down an SQL statement to modify an existing tuple in AUTHOR which would yield a key integrity violation. The modification should not violate any other integrity constraints.

Writing SQL queries is not covered in the final exam.

Answer:

```
UPDATE AUTHOR
SET aid = 2
WHERE name = "S.E.Hinton";
```

- Write down an SQL statement to insert a tuple into BOOK which would yield an entity integrity violation. The insertion should not violate the existing foreign key constraint.

Answer:

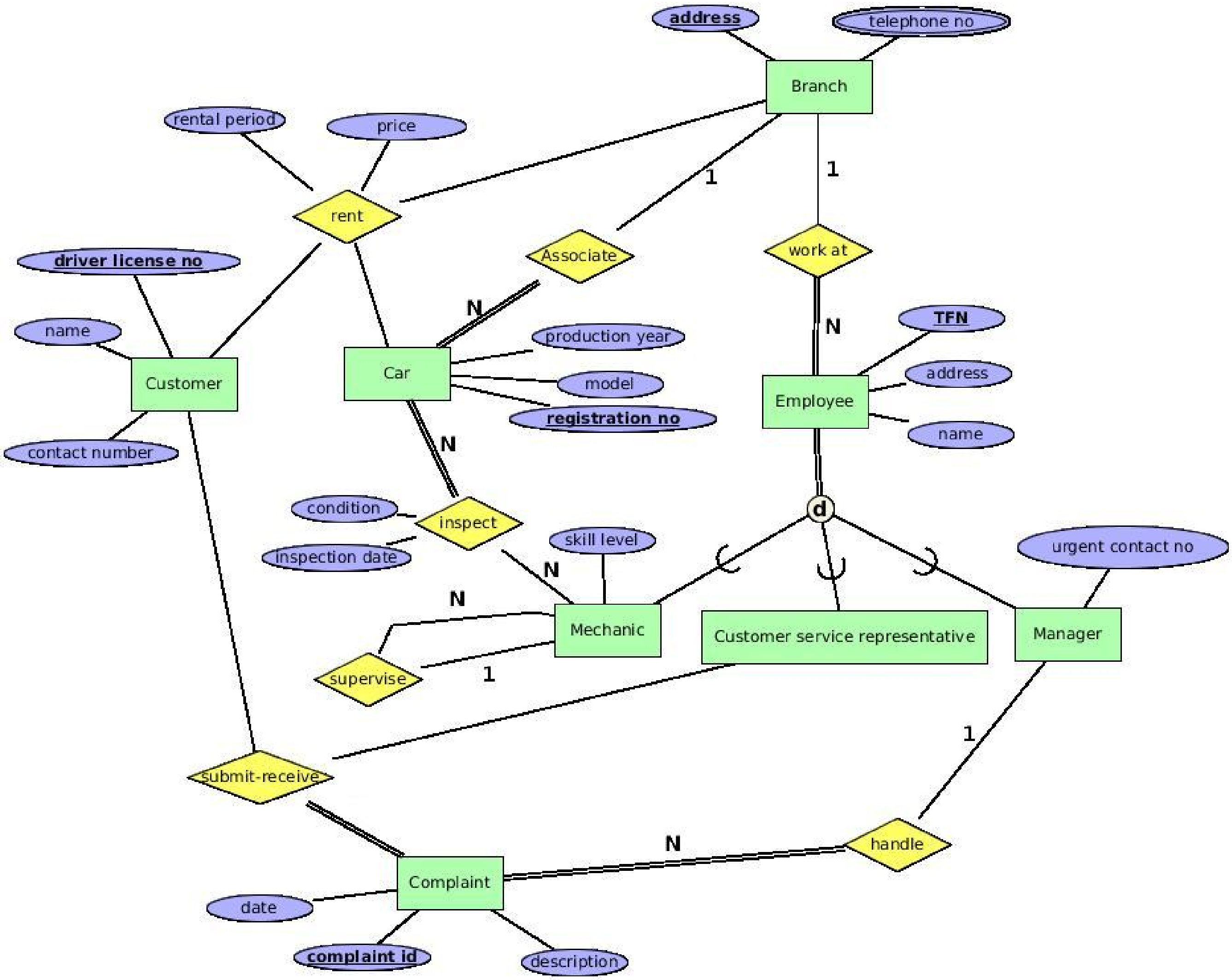
```
INSERT INTO BOOK
VALUES (NULL, "Fire", English, 1980, 1);
```

Note the original Question 2 is replaced by this question to keep up with our current course materials.

Question 2: ER Modelling and Translation [8 marks]

ACTRides is a car rental company which has been founded recently in Canberra. It currently has 5 branches opened in Acton, Belconnen, Dickson, Braddon and Woden, respectively. ACTRides is planning to expand to areas such as Tuggeranong and Manuka in the future. A branch has a unique address but may have multiple telephone numbers. Each rental car must be associated with exactly one ACTRides branch. A rental car can be identified by its registration number and has the information about the model and the production year. Each employee working at ACTRides has a tax file number (TFN), a name and an address. ACTRides employees consist of managers, mechanics and customer service representatives. Every employee must work at exactly one branch. A customer of ACTRides should provide their drivers license number, their name and a contact number. A customer can rent a car from an ACTRides branch and details about the rental such as the rental period and price should be recorded. If a customer is not satisfied with the rental service provided, this customer may submit a complaint to a customer service representative and thus a distinct reference number and detailed description of the complaint should be recorded. The manager of a branch will handle all the complaints with respect to this branch and has an urgent contact number in case of emergency. Mechanics working at a branch inspect the cars associated with the branch and record the condition and inspection date. A car must be inspected at least two times per year. Each mechanic has a skill level and might have another mechanic as the supervisor. The supervisor must have a higher skill level compared to the mechanics supervised by this supervisor.

Your task is to design an Enhanced Entity Relationship (EER) diagram for the above database, which should include entities, relationships, attributes and constraints wherever appropriate (you can make more assumptions if necessary).



You also need to identify the requirements that cannot be captured in an EER-diagram.

Requirements that cannot be captured in the EER-diagram:

- A car must be inspected at least two times per year.
- The supervisor must have a higher skill level compared to the mechanics supervised by this supervisor.

Question 3: Functional Dependencies and Normal Forms [15 marks]

3. a Satisfaction of Functional Dependencies [4 marks]

3. a (i) [3 marks]

Consider two relations $r_1(R)$ and $r_2(R)$ over the same relation schema $R(A, B, C, D)$.

$r_1(R)$

A	B	C	D
1	2	3	1
4	5	3	2
4	3	3	2
1	5	2	3

$r_2(R)$

A	B	C	D
1	2	3	2
1	4	5	3
3	4	2	4

The following is a table (i.e., Table 1) with a column for each of these relations and a row for a functional dependency. Enter "yes" or "no" in each cell of the table, indicating whether the relation satisfies the functional dependency.

Answer:

	$r_1(R)$	$r_2(R)$
$A \longrightarrow B$	no	no
$AB \longrightarrow C$	yes	yes
$A \longrightarrow BC$	no	no
$DC \longrightarrow B$	no	yes
$BC \longrightarrow B$	yes	yes
$AD \longrightarrow C$	yes	yes

Table 1: Functional dependencies

3. a (ii) [1 mark]

Are there any trivial functional dependencies shown in Table 1? If any, specify them and explain why they are trivial.

Answer: $BC \longrightarrow B$ is trivial.

3. b Candidate Keys and Normal Forms [4 marks]

Given a relation schema $R(A, B, C, D, E)$ with the following set Σ of functional dependencies:

$$\Sigma = \{A \longrightarrow C, CE \longrightarrow B, BC \longrightarrow AD \text{ and } D \longrightarrow E\}.$$

3. b (i) [1 mark]

Does $AB \longrightarrow E$ hold on any relation of R that satisfies Σ? If so, explain why; otherwise, give a counterexample.

Answer: Compute the closure of AB w.r.t. Σ: (AB)$^+$ = (ABC)$^+$ = (ABCD)$^+$ = (ABCDE)$^+$ =ABCDE. Because $E \in (AB)^+$ holds, $AB \longrightarrow E$ holds on any relation of R that satisfies Σ.

3. b (ii) [3 marks]

Is R in BCNF? If not, normalise R into BCNF. Explain your answer.

Answer:

- Step 1: check whether the left hand side of each FD is a superkey:
  - (A)$^+$ = AC
  - (CE)$^+$ = (BCE)$^+$ = (ABCDE)$^+$ =ABCDE
  - (BC)$^+$ = (ABCD)$^+$ = (ABCDE)$^+$ =ABCDE
  - (D)$^+$ = DE
- Step 2: $A \longrightarrow C$ and $D \longrightarrow E$ are problematic, so we decompose R along them into:
  - AC with $\{A \longrightarrow C\}$
  - DE with $\{D \longrightarrow E\}$
  - ABD

3. c Candidate Keys and Normal Forms [7 marks]

Consider the relation schema

MEETING(OfficerID, OfficerName, CustNo, CustName, Date, Time, Room),

and the following set of functional dependencies on MEETING:

- OfficerID $\longrightarrow$ OfficerName;
- OfficerID, Date $\longrightarrow$ Room;
- CustNo $\longrightarrow$ CustName;
- CustNo, Date, Time $\longrightarrow$ OfficerID;
- Date, Time, Room $\longrightarrow$ CustNo.

3. c (i) [1 mark]

Discuss the anomalies in the current schema MEETING and identify at least two potential problems.

Answer: Refer to the text book and the lecture notes about insert anomalies, delete anomalies and modification anomalies.

3. c (ii) [2 marks]

Find out all the candidate keys and prime attributes of MEETING.

Answer: Compute the closure of attributes (refer to the lecture nodes). The candidate keys are:

- $\{$CustNo, Date, Time$\}$
- $\{$OfficerID, Date, Time$\}$

- {Data, Time, Room}

The prime attributes are {CustNo, OfficeID, Date, Time, Room}.

3. c (iii) [1 mark]

As we have not discussed 1NF and 2NF in S2 2020, you can skip this question when preparing for the final exam.

What is the highest normal form of MEETING with respect to the given set of functional dependencies? Explain the reason.

Note:

- We only consider the normal forms 1NF, 2NF, 3NF and BCNF (in increasing order of strength).
- No primary keys are given, so the relevant definitions of the normal forms are the ones that refer to *all* candidate keys.

Answer: The highest normal form of MEETING is 1NF because OfficerID $\longrightarrow$ OfficerName and CustNo $\longrightarrow$ CustName are partial dependencies with respect to the candidate keys.

3. c (iv) [3 marks]

Normalise the relation schema MEETING into BCNF.

As we have not discussed 2NF in S2 2020, please ignore the sample solution to this question when preparing for the final exam.

Answer: There are several steps:

- Normalise MEETING into 2NF along OfficerID $\longrightarrow$ OfficerName and CustNo $\longrightarrow$ CustName:
  - OFFICE(OfficeID, OfficeName) with the FD: OfficerID $\longrightarrow$ OfficerName
  - CUSTOMER(CustNo, CustName) with the FD: CustNo $\longrightarrow$ CustName
  - MEETING'(OfficerID, CustNo, Date, Time, Room) with the FDs:
    - ∗ OfficerID, Date $\longrightarrow$ Room;
    - ∗ CustNo, Date, Time $\longrightarrow$ OfficerID;
    - ∗ Date, Time, Room $\longrightarrow$ CustNo.
- Normalise MEETING' into BCNF along OfficerID, Date $\longrightarrow$ Room:
  - MEETING''(OfficerID, Date, Room) with the FD: OfficerID, Date $\longrightarrow$ Room;
  - MEETING'''(OfficerID, CustNo, Date, Time) with the FD: CustNo, Date, Time $\longrightarrow$ OfficerID.

Hence, MEETING can be decomposed into the following four relations in BCNF:

- OFFICE, CUSTOMER,MEETING'' and MEETING'''

Question 4: Relational Algebra and Query Processing [18 marks]

4. a Relational Algebra Expressions [4 marks]

Consider the following relation schemas:

AUTHOR(aid, name) with the primary key {aid};

BOOK(bid, title, language, date, aid) with the primary key {bid} and
the foreign key [aid]⊆ AUTHOR[aid].

Write relational algebra expressions for the following queries.

4. a (i) [1 mark]

Who wrote the book titled “The Cat in the Hat”?

Answer:

- $\pi_{name}(\sigma_{title=\text{“}The\ Cat\ in\ the\ Hat\text{”}}(\text{BOOK}) \bowtie \text{AUTHOR})$, or
- $\pi_{aid,name}(\sigma_{title=\text{“}The\ Cat\ in\ the\ Hat\text{”}}(\text{BOOK}) \bowtie \text{AUTHOR})$

4. a (ii) [1 mark]

List the names of authors who have published at least one book in English and one book in Japanese.

Answer:

- $\pi_{name}((\pi_{aid}(\sigma_{Language=\text{“}English\text{”}}(\text{BOOK})) \bowtie \pi_{aid}(\sigma_{Language=\text{“}Japanese\text{”}}(\text{BOOK}))) \bowtie \text{AUTHOR})$

- $\pi_{name}((\pi_{aid}(\sigma_{Language=\text{“}English\text{”}}(\text{BOOK})) \cap \pi_{aid}(\sigma_{Language=\text{“}Japanese\text{”}}(\text{BOOK}))) \bowtie \text{AUTHOR})$

4. a (iii) [2 marks]

Find out the authors who have never published a book in English.

Answer:

- $\pi_{aid,name}(\text{AUTHOR}) - \pi_{aid,name}(\sigma_{language=\text{``}English\text{''}}(\text{BOOK} \bowtie \text{AUTHOR}))$

4. b Evaluation [5 marks]

Suppose that we have the relations ANIMAL and COLOR shown in Figure 3.

ANIMAL

A	B	C
1	white	cat
2	brown	rabbit
3	white	bird
4	red	bird

COLOR

D	E
1	brown
2	white
3	blue

Figure 3: Relations ANIMAL and COLOR

Evaluate the following relational algebra expressions. Show your answer as a table, like those in Figure 3.

4. b (i) [1 mark]

Evaluate $\pi_C(\sigma_{B='white'}(\text{ANIMAL}))$.
Answer:

C				
cat				
bird				

4. b (ii) [1 mark]

Evaluate $\pi_B(\text{ANIMAL}) \cup \rho_{(B)}(\pi_E(\text{COLOR}))$.
Answer:

B				
white				
brown				
red				
blue				

4. b (iii) **[1 mark]**

Evaluate $\pi_{A,C,E}(\text{ANIMAL} \bowtie_{B=E} \text{COLOR})$.

Answer:

A	C	E		
1	cat	white		
2	rabbit	brown		
3	bird	white		

4. b (iv) **[2 marks]**

Evaluate $(\sigma_{B='white'}(\text{ANIMAL})) \times \pi_E(\text{COLOR})$

Answer:

A	B	C	E	
1	white	cat	brown	
1	white	cat	white	
1	white	cat	blue	
3	white	bird	brown	
3	white	bird	white	
3	white	bird	blue	

4. c Relational Algebra Operators [5 marks]

4. c (i) [1 mark]

List the six basic relational algebra operators that constitute a complete set in relational algebra.

Answer:

1. selection σ;
2. projection π;
3. renaming ρ;
4. union $\cup$;
5. difference –;
6. Cartesian product $\times$.

4. c (ii) [1 mark]

Define the operator *join* in terms of the six basic operators in relational algebra.

Answer:

- $R_1 \bowtie_\varphi R_2 = \sigma_\varphi(R_1 \times R_2)$

4. c (iii) [1 mark]

Suppose that two relations R and Q have exactly the same schema. Which of the following statements are true in relational algebra?

1. $R \cap Q = R - (R - Q)$
2. $R \cap Q = Q - (Q - R)$
3. $R \cap Q = R \times Q$
4. $R \cap Q = R \bowtie Q$

Answer:

- (1), (2) and (4)

4. c (iv) [2 marks]

Consider the following statements of relational algebra. Does each of them hold for any relation R? Justify your answer.

1. $\sigma_A(\sigma_B(R)) = \sigma_B(\sigma_A(R))$

   Answer:

   Yes, it holds by the commutativity property of σ.

2. $\pi_X(\pi_Y(R)) = \pi_X(R)$

   Answer:

   No, it only holds under the condition $X \subseteq Y$.

4. d Query Processing [4 marks]

Consider the following relation schemas:

- MOVIE(title, production_year, country) with the primary key {title, production_year};
- PERSON(id, first_name, last_name, year_born) with the primary key {id};
- DIRECTOR(pid, title, production_year) with the primary key {pid}
  and the foreign keys:

  [pid] $\subseteq$ PERSON[id];

  [title, production_year] $\subseteq$ MOVIE[title, production_year].

4. d (i) [2 marks]

Translate the following SQL query into a relational algebra expression, and then draw the query tree correspondingly.

```
SELECT MOVIE.title, PERSON.first_name
FROM MOVIE, PERSON, DIRECTOR
WHERE MOVIE.title = DIRECTOR.title
AND DIRECTOR.pid=PERSON.id
AND MOVIE.country= 'USA';
```

Answer:

- Relational algebra expression:
  - $\pi_{Movie.title, Person.first\_name}$
    $(\sigma_{Movie.title=Director.title \wedge Director.pid=Person.id \wedge Movie.country='USA'}$
    $(\text{MOVIE} \times \text{DIRECTOR} \times \text{PERSON}))$

4. d (ii) [2 marks]

Optimise your tree by applying at least two different transformation rules of relational algebra studied in lectures.

Answer:

- Since country is an attribute of MOVIE, by the rule $\sigma_{\varphi}(R_1 \bowtie R_2) \equiv R_1 \bowtie \sigma_{\varphi}(R_2)$, if R_1 is unaffected by φ, we have
  - $\pi_{Movie.title, Person.first\_name}$
    $(\sigma_{Movie.title=Director.title \wedge Director.pid=Person.id}$
    $(\sigma_{country='USA'}(\text{MOVIE}) \times \text{DIRECTOR} \times \text{PERSON}))$
- Since first_name is an attribute of PERSON, by the rule $\pi_X(R_1 \bowtie R_2) \equiv \pi_X(\pi_{X_1}(R_1) \bowtie \pi_{X_2}(R_2))$, where X_i contains attributes both in R_i and X, and ones both in R_1, we have:
  - $\pi_{Movie.title, Person.first\_name}$
    $(\sigma_{Movie.title=Director.title \wedge Director.pid=Person.id}$
    $(\pi_{title,pid}(\sigma_{country='USA'}(\text{MOVIE}) \times \text{DIRECTOR}) \times \pi_{id,first\_name}(\text{PERSON})))$
- Further optimization can be applied, for example, pushing the selection condition $Movie.title = Director.title \wedge Director.pid = Person.id$ down into the joins, i.e.,
  - $\pi_{Movie.title, Person.first\_name}$
    $(\pi_{title,pid}(\sigma_{country='USA'}(\text{MOVIE}) \bowtie_{Movie.title=Director.title} \text{DIRECTOR})$
    $\bowtie_{Director.pid=Person.id} (\pi_{id,first\_name}(\text{PERSON})))$

The general idea is to apply *push-down selection* and *push-down projection*.

Question 5: Transactions and Security [7 marks]

5. a [1 mark]

What are the ACID properties?

(1) atomicity, constant, isolation, durability

(2) atomicity, consistency, isolation, duration

(3) atomicity, consistency, isolation, durability

(4) atomicity, consistency, indexing, durability

(5) atomicity, constant, indexing, durability

Answer: (3)

5. b [2 marks]

Suppose that there is no concurrency control for the following transactions T_1 and T_2. What kind of problem can occur in this case?

T_1	T_2
readItem(Y)	
writeItem(Y)	
	readItem(X)
	readItem(Y)
	writeItem(Y)
readItem(X)	
abort	

Answer: The dirty read problem. The explanation about how this problem might occur in this case should be provided (refer to the text book and the lecture notes).

5. c [2 marks]

Consider the following SQL code built by an application, in which the email address tom@gmail.com was entered by the user:

SELECT name, password FROM PERSON WHERE email = ’tom@gamil.com’;

Show how an SQL injection attack can happen in this case.

Answer: an SQL injection injects a string input through the Web application which changes the SQL statement to their advantage.

```
SELECT name, password
FROM PERSON
WHERE email = ’tom@gamil.com’ OR ‘x’=‘x’;
```

5. d [2 marks]

Consider the table PROJECT that has been created in a relational database.

5. d (i) [1 mark]

Use SQL to give the read and update privileges on table PROJECT to Bob.

Answer:

- grant SELECT, UPDATE on PROJECT TO Bob;

5. d (ii) [1 mark]

Use SQL to cancel Bob’s update privilege on table PROJECT.

Answer:

- revoke UPDATE on PROJECT from Bob;