1. Specify the following queries on the COMPANY relational database schema shown in Figure 5.5, using the relational operators discussed in this chapter. Also show the result of each query as it would apply to the database state of Figure 5.6.

(a) Retrieve the names of employees in department 5 who work more than 10 hours per week on the 'ProductX' project.

(b) List the names of employees who have a dependent with the same first name as themselves.

(c) Find the names of employees that are directly supervised by 'Franklin Wong'.

(d) For each project, list the project name and the total hours per week (by all employees) spent on that project.

(e) Retrieve the names of employees who work on every project.

(f) Retrieve the names of employees who do not work on any project.

(g) For each department, retrieve the department name, and the average salary of employees working in that department.

(h) Retrieve the average salary of all female employees.

(i) Find the names and addresses of employees who work on at least one project located in Houston but whose department has no location in Houston.

(j) List the last names of department managers who have no dependents.

**Answers:**

In the relational algebra, as in other languages, it is possible to specify the same query in multiple ways. We give one possible solution for each query.

(a) \[ EMP_{W\_X} \leftarrow (\sigma_{\text{PNAME}='ProductX'}(\text{PROJECT})) \bowtie_{\text{PNUMBER}=\text{PNO}}(\text{WORKS\_ON}) \]

\[ EMP_{WORK\_10} \leftarrow (\text{EMPLOYEE}) \bowtie_{\text{SSN}=\text{ESSN}}(\sigma_{\text{HOURS}>10}(\text{EMP_{W\_X}})) \]

\[ \text{RESULT} \leftarrow \Pi_{\text{LNAME}, \text{FNAME}}(\sigma_{\text{DNO}=5}(\text{EMP_{WORK\_10}})) \]

Result:

<table>
<thead>
<tr>
<th>LNAME</th>
<th>FNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smith</td>
<td>John</td>
</tr>
<tr>
<td>English</td>
<td>Joyce</td>
</tr>
</tbody>
</table>
(b) $E \leftarrow (\text{EMPLOYEE}) \bowtie_{\text{SSN}=\text{ESSN AND FNAME}=\text{DEPENDENT_NAME}} (\text{DEPENDENT})$

$R \leftarrow \Pi_{\text{LNAME,FNAME}} (E)$

Result (empty):

<table>
<thead>
<tr>
<th>LNAME</th>
<th>FNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(c) $\text{WONG_SSN} \leftarrow \Pi_{\text{SSN}} (\sigma_{\text{FNAME}=\text{Franklin AND LNAME}=\text{Wong}} (\text{EMPLOYEE}))$

$\text{WONG_EMPS} \leftarrow (\text{EMPLOYEE}) \bowtie_{\text{SUPERSSN}=\text{SSN}} (\text{WONG_SSN})$

$\text{RESULT} \leftarrow \Pi_{\text{LNAME,FNAME}} (\text{WONG_EMPS})$

Result:

<table>
<thead>
<tr>
<th>LNAME</th>
<th>FNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smith</td>
<td>John</td>
</tr>
<tr>
<td>Narayan</td>
<td>Ramesh</td>
</tr>
<tr>
<td>English</td>
<td>Joyce</td>
</tr>
</tbody>
</table>

(d) $\text{PROJ_HOURS(PNO,TOT_HRS)} \leftarrow \Pi_{\text{PNO}} \sum_{\text{SUM HOURS}} (\text{WORKS_ON})$

$\text{RESULT} \leftarrow \Pi_{\text{PNAME,TOT_HRS}} ( (\text{PROJ_HOURS}) \bowtie_{\text{PNO}=\text{PNUMBER}} (\text{PROJECT}) )$

Result:

<table>
<thead>
<tr>
<th>PNAME</th>
<th>TOT_HRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProductX</td>
<td>52.5</td>
</tr>
<tr>
<td>ProductY</td>
<td>37.5</td>
</tr>
<tr>
<td>ProductZ</td>
<td>50.0</td>
</tr>
<tr>
<td>Computerization</td>
<td>55.0</td>
</tr>
<tr>
<td>Reorganization</td>
<td>25.0</td>
</tr>
<tr>
<td>Newbenefits</td>
<td>55.0</td>
</tr>
</tbody>
</table>

(e) $\text{PROJ_EMPS(PNO,SSN)} \leftarrow \Pi_{\text{PNO,ESSN}} (\text{WORKS_ON})$

$\text{ALL_PROJS(PNO)} \leftarrow \Pi_{\text{PNUMBER}} (\text{PROJECT})$

$\text{EMPS_ALL_PROJS} \leftarrow \text{PROJ_EMPS} \div \text{ALL_PROJS}$

$\text{RESULT} \leftarrow \Pi_{\text{LNAME,FNAME}} (\text{EMPLOYEE} \ast \text{EMP_ALL_PROJS})$

Result (empty):

<table>
<thead>
<tr>
<th>LNAME</th>
<th>FNAME</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(f) $\text{ALL_EMPS} \leftarrow \Pi_{\text{SSN}} (\text{EMPLOYEE})$

$\text{WORKING_EMPS(SSN)} \leftarrow \Pi_{\text{ESSN}} (\text{WORKS_ON})$
NON_WORKING_EMPS ← ALL_EMPS - WORKING_EMPS

RESULT ← \( \Pi \text{LNAME},\text{FNAME} \) (EMPLOYEE \* NON_WORKING_EMPS)

Result (empty):
LNAME    FNAME

(g) DEPT_AVG_SALS(DNUMBER, AVG_SAL) ← DNO \( \exists \) AVG_SALARY (EMPLOYEE)

RESULT ← \( \Pi \text{DNAME},\text{AVG_SAL} \) (DEPT_AVG_SALS \* DEPARTMENT)

Result:
DNAME    AVG_SAL
Research  33250
Administration  31000
Headquarters  55000

(h) RESULT(AVG_F_SAL) ← \( \exists \) AVG_SALARY (\( \sigma \text{SEX}='F' \) (EMPLOYEE))

Result:
AVG_F_SAL 31000

(i) E_P_HOU(SSN) ←

\( \Pi \text{ESSN} \) (WORKS_ON\( \times \)PNO=PNUMBER (\( \sigma \) PLOCATION='Houston' (PROJECT)))

D_NO_HOU ←

\( \Pi \text{DNUMBER} \) (DEPARTMENT) - \( \Pi \text{DNUMBER} \) (\( \sigma \) DLOCATION='Houston' (DEPARTMENT))

E_D_NO_HOU ← \( \Pi \text{SSN} \) (EMPLOYEE\( \times \)PNO=DNUMBER (D_NO_HOU))

RESULT_EMPS ← E_P_HOU - E_D_NO_HOU

RESULT ← \( \Pi \text{LNAME},\text{FNAME},\text{ADDRESS} \) (EMPLOYEE \* RESULT_EMPS)

Result:
LNAME    FNAME    ADDRESS
Wallace  Jennifer   291 Berry, Bellaire, TX

(j) DEPT_MANAGERS(SSN) ← \( \Pi \text{MGRSSN} \) (DEPARTMENT)

EMPS_WITH_DEPENDENTS(SSN) ← \( \Pi \text{ESSN} \) (DEPENDENT)
RESULT_EMPS ← DEPT_MANAGERS - EMPS_WITHDEPENDENTS

RESULT ← \( \Pi_{\text{LNAME, FName}} \text{(EMPLOYEE} \ast \text{RESULT_EMPS)} \)

Result:

<table>
<thead>
<tr>
<th>LNAME</th>
<th>FName</th>
</tr>
</thead>
<tbody>
<tr>
<td>Borg</td>
<td>James</td>
</tr>
</tbody>
</table>

2.

(a) \( R_1 \leftarrow \text{STUDENT} \bowtie_{\text{S.SSN}=\text{E.SSN}} \text{ENROLL} \)

\( R_2 \leftarrow \Pi_{\text{COURSE#}} \sigma_{\text{name}='JOHN SMITH' \text{AND quarter}='W99'} (R_1) \)

Answer: \( R_2 \)

(b) \( R_1 \leftarrow \text{COURSE} \bowtie_{\text{C.COURSE#}=\text{B.COURSE#}} \text{BOOK ADOPTION} \)

\( R_2(\text{COURSE#, BOOK_NO}) \leftarrow \Pi_{\text{COURSE#}} \exists_{\text{COUNT} \text{BOOK ISBN} (R_1)} \)

\( R_3 \leftarrow \sigma_{\text{CNAME}=\text{CS} \text{AND BOOK_NO}>2} (\text{COURSE} \bowtie_{\text{C.COURSE#}=\text{R2.COURSE#}} R_2) \)

\( R_4 \leftarrow \Pi_{\text{COURSE#, BOOK ISBN}} (R_3 \bowtie_{\text{R3.COURSE#}=\text{B.COURSE#}} \text{BOOK ADOPTION}) \)

\( R_5 \leftarrow \Pi_{\text{COURSE#, BOOK ISBN, BOOK TITLE}} (R_4 \bowtie_{\text{R4.BOOK ISBN}=\text{T.BOOK ISBN TEXT}} \text{TEXT}) \)

Answer: \( R_5 \)

(c) \( R_1 \leftarrow \Pi_{\text{COURSE#, PUBLISHER}} (\text{BOOK ADOPTION} \bowtie_{\text{B.BOOK ISBN}=\text{T.BOOK ISBN TEXT}}) \)

\( R_2 \leftarrow \sigma_{\text{COUNT_PUB}=1} (\text{COURSE} \bowtie_{\text{COUNT PUBLISHER} (R_1)} \text{TEXT}) \)

\( R_3 \leftarrow \sigma_{\text{PUBLISHER}=\text{AWL Publishing}} (R_2 \bowtie_{\text{R2.COURSE#}=\text{R1.COURSE#}} R_1) \)

\( R_4 \leftarrow \Pi_{\text{CNAME}} (\text{COURSE} \bowtie_{\text{C.COURSE#}=\text{R3.COURSE#}} \text{R3}) \)

Answer: \( R_4 \)
3.

Answer:

(a) P Q R A B C
10 a 5 10 b 6
10 a 5 10 b 5
25 a 6 25 c 3
(b) P Q R A B C
15 b 8 10 b 6
15 b 8 10 b 5
(c) P Q R A B C
10 a 5 10 b 6
10 a 5 10 b 5
15 b 8 null null null
25 a 6 25 c 3
(d) P Q R A B C
15 b 8 10 b 6
null null null 25 c 3
15 b 8 10 b 5
(e) P Q R
10a 5
15 b 8
25 a 6
10b 6
25 c 3
10b 5
(f) P Q R A B C
10 a 5 10 b 5

4. Specify queries (a), (b), (c), (e), (f), (i), and (j) of Question 1 in both the tuple relational calculus and the domain relational calculus.

Answer:

(a) Retrieve the names of employees in department 5 who work more than 10 hours per week on the 'ProductX' project.

Tuple relational Calculus:

\{ e.LNAME, e.FNAME | EMPLOYEE(e) AND e.DNO=5 AND (\exists p) (\exists w) (WORKS_ON(w) AND PROJECT(p) AND e.SSN=w.ESSN AND w.PNO=p.PNUMBER AND p.PNAME='ProductX' AND w.HOURS>10 ) \} 

Domain relational Calculus:
(b) List the names of employees who have a dependent with the same first name as themselves.

Tuple relational Calculus:

\{ e.LNAME, e.FNAME | EMPLOYEE(e) AND (∃ d) ( DEPENDENT(d) AND e.SSN=d.ESSN AND e.FNAME=d.DEPENDENT_NAME ) \}

Domain relational Calculus:

\{ qs \mid (\exists t) (\exists a) (\exists b) ( EMPLOYEE(qrstuvwxyz) AND DEPENDENT(abcdefghij) AND a=t AND b=q ) \}

(c) Find the names of employees that are directly supervised by 'Franklin Wong'.

Tuple relational Calculus:

\{ e.LNAME, e.FNAME | EMPLOYEE(e) AND (∃ s) ( EMPLOYEE(s) AND s.FNAME='Franklin' AND s.LNAME='Wong' AND e.SUPERSSN=s.SSN ) \}

Domain relational Calculus:

\{ qs \mid (\exists y) (\exists a) (\exists c) (\exists d) ( EMPLOYEE(qrstuvwxyz) AND EMPLOYEE(abcdefghij) AND a='Franklin' AND c='Wong' AND y=d ) \}

(e) Retrieve the names of employees who work on every project.

Tuple relational Calculus:

\{ e.LNAME, e.FNAME | EMPLOYEE(e) AND (FORALL p) ( NOT(PROJECT(p)) OR (∃ w) ( WORKS_ON(w) AND p.PNUMBER=w.PNO AND w.ESSN=e.SSN ) ) \}

Domain relational Calculus:

\{ qs \mid (\exists t) ( EMPLOYEE(qrstuvwxyz) AND (FORALL b) (NOT(PROJECT(abcd)) OR (∃ e) (∃ f) (WORKS_ON(efg) AND e=t AND f=b ) ) \}
(f) Retrieve the names of employees who do not work on any project.

Tuple relational Calculus:

\[ \{ e.LNAME, e.FNAME | EMPLOYEE(e) \text{ AND NOT}(\exists w) (WORKS_ON(w) \text{ AND } w.ESSN=e.SSN) \} \]

Domain relational Calculus:

\[ \{ qs | (\exists t) (EMPLOYEE(qrstuvwxyz) \text{ AND NOT}(\exists a) (WORKS_ON(abc) \text{ AND } a=t) ) \} \]

(i) Find the names and addresses of employees who work on at least one project located in Houston but whose department has no location in Houston.

Tuple relational Calculus:

\[ \{ e.LNAME, e.FNAME, e.ADDRESS | EMPLOYEE(e) \text{ AND } (\exists p) (\exists w) (WORKS_ON(w) \text{ AND PROJECT(p) AND } e.SSN=w.ESSN \text{ AND } w.PNO=p.PNUMBER \text{ AND } p.PLOCATION='Houston' \text{ AND NOT}(\exists l) (DEPT_LOCATIONS(l) \text{ AND } e.DNO=l.DNUMBER \text{ AND } l.DLOCATION='Houston') ) \} \]

Domain relational Calculus:

\[ \{ qsv | (\exists t) (\exists z) (EMPLOYEE(qrstuvwxyz) \text{ AND } (\exists b) (\exists c) (\exists e) (\exists f) (WORKS_ON(efg) \text{ AND PROJECT(abcd) AND } t=e \text{ AND } f=b \text{ AND } c='Houston' \text{ AND NOT}(\exists h) \text{ NOT}(\exists i) (DEPT_LOCATIONS(hi) \text{ AND } z=h \text{ AND } i='Houston')) ) \} \]

(j) List the last names of department managers who have no dependents.

Tuple relational Calculus:

\[ \{ e.LNAME | EMPLOYEE(e) \text{ AND } (\exists d) (DEPARTMENT(d) \text{ AND } e.SSN=d.MGRSSN \text{ AND NOT}(\exists x) (DEPENDENT(x) \text{ AND } e.SSN=x.ESSN) ) \} \]

Domain relational Calculus:

\[ \{ s | (\exists t) (EMPLOYEE(qrstuvwxyz) \text{ AND } (\exists c) (DEPARTMENT(abcd) \text{ AND } t=c \text{ AND NOT}(\exists e) (DEPENDENT(efghi) \text{ AND } e=t) ) \} \]