Information Management II

4. Relational Algebra

CS4D2a – 4CSLL1 – CS3041
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Relational Algebra

- A data model must include a set of operations to manipulate the database
  - Relational Algebra is this basic set of operations for the Relational Model
- Relational Algebra is important, as it:
  - provides a formal foundation for relational model operations
  - is used as a basis for implementing and optimizing queries
  - is incorporated into the SQL language for RDBMS

Relational Algebra

- Relational Algebra is a collection of operations on relations which fall into two groups:
  - Set operations from mathematical set theory
    - union, intersection, etc.
    - Applicable as each relation is defined to be a set of tuples in the relational model
  - Relational operations
    - Defined specifically for relational databases
    - selection, projection, join, etc.

Relational Algebra Operations

- Set Operations
  - Standard mathematical operations on sets
  - UNION, INTERSECTION, SET DIFFERENCE
- Relational Database Operations
  - Unary Operations
    - Operate on a single relation
    - SELECT and PROJECT
  - Binary Operations
    - A JOIN is used to combine related tuples across two relations using a *join condition*

Selection

- The SELECT operation is used to identify the subset of tuples from a relation that satisfy a selection condition
  - Acts as a filter on a relation
  - Horizontal partition of a relation
- Formal Notation
  - $\sigma_{(\text{select condition})}(R)$

Selection

- So to identify all employees in department 4

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

– $\sigma_{(\mathrm{Dno}=4)}(\mathrm{EMPLOYEE})$

Selection

- The result of the SELECT operation is a new relation
  - Made up of those tuples that satisfied the selection condition

Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4

- This new relation has the same attributes as the relation R, upon which the selection was performed

Selection

- Boolean Expression specified in the (selection condition) is made up of a number of clauses:
  - <attribute name> <comparison op> <constant value>
- <attribute name>
  - name of an attribute of R
- <comparison op>
  - operator such as $= < \leq > \geq \neq$
- <constant value>
  - a constant value from the attribute domain

Selection

- Selection conditions can be joined by boolean operators *and*, *or* and *not*
  - (cond1 AND cond2) is TRUE if both (cond1) and (cond2) are TRUE; otherwise, it is FALSE.
  - (cond1 OR cond2) is TRUE if either (cond1) or (cond2) or both are TRUE; otherwise, it is FALSE.
  - (NOT cond) is TRUE if cond is FALSE; otherwise, it is FALSE.

Selection

- Example:
- Select all employees who either work in department 4 and make over €25,000 a year or work in department 5 and make over €30,000 a year

$$\sigma_{(\text{Dno}=4 \text{ AND } \text{Salary}>25000) \text{ OR } (\text{Dno}=5 \text{ AND } \text{Salary}>30000)}(\text{EMPLOYEE})$$

Selection

- Rather than using a constant value to evaluate the selection condition, another attribute can be used
  - <attribute name> <comparison op> <attribute name>
- Example: select all employees who earn more than the lower tax band
  - $\sigma_{(\text{Salary} > \text{lower\_tax\_band})}(\text{EMPLOYEE})$

Selection

- Full set of comparison operators ($= < \leq > \geq \neq$) can be used on all *Ordered Domains*
  - Numeric, Currency, Dates
- Can also have *Unordered Domains*
  - i.e. Color = {Red, Blue, Green, Yellow,…}
- Only valid comparison operators
  - {= , ≠ }
  - Exceptions - substring

Selection

- The Select operator is Unary
  - Applied to a single relation
  - Select is applied to each tuple in turn
- Degree
  - The degree is the number of attributes in the relation
  - The degree of the Select operator is the same as the degree of the relation R

Selection

- The number of tuples returned for a Select operation, is always less than or equal to the number of tuples in R

$$\left|\sigma_c\left(R\right)\right| \leq \left|R\right|$$

- The fraction of tuples in a relation selected by a condition is known as the ***selectivity*** of that condition

Selection

- The Select operation is ***commutative***
  - $\sigma_{(\text{condition 1})}(\sigma_{(\text{condition 2})}(R))$
  - $\sigma_{(\text{condition 2})}(\sigma_{(\text{condition 1})}(R))$
- A "***cascade***" or sequence of select operations can be combined into a single operation
  - $\sigma_{(\text{condition 1})}(\sigma_{(\text{condition 2})}(\ldots(\sigma_{(\text{condition n})}(R))\ldots))$
  - $\sigma_{(\text{condition 1}) \text{ AND } (\text{condition 2}) \text{ AND } \ldots \text{ AND } (\text{condition n})}(R)$

Selection in SQL

- SELECT is a common command in SQL, directly based upon this Relational Algebra approach
- While the algebraic notation is:
  - $\sigma_{(\text{Dno}=4 \text{ AND } \text{Salary}>25000)}(\text{EMPLOYEE})$
- The SQL syntax is:

```
SELECT * from EMPLOYEE
WHERE Dno = 4
AND Salary > 25,000;
```

Projection

- The Project operation selects certain attributes from the table, while discarding the others
  - Vertical partition of a relation
- Formal Notation
  - $\pi_{\text{attribute list}}(R)$
- Example: to list all employees first and last names and their salary, we can use Project:
  - $\pi_{\text{Fname, Lname, Salary}}(\text{EMPLOYEE})$

Projection

- The relation that is the result of the Project operation has only the attributes specified in the attribute list
  - Hence, the *degree* of the resulting relation is equal to the number of attributes in this list

Projection

- Duplicate Elimination
  - It is possible for a Project operation to specify a set of non-key attributes, i.e. forename and surname
  - In this instance, duplicate tuples are likely to occur
  - However, the result of a Project operation has to be a valid relation, and only contain distinct tuples
  - The operation removes (or merges) the duplicate tuples and only returns distinct tuples

Projection in SQL

- The SELECT statement in SQL also handles the Project operation
- While the algebraic notation is:
  - $\pi_{\text{Fname, Lname, Salary}}(\text{EMPLOYEE})$
- The SQL syntax is:

```
SELECT Fname, Lname, Salary
from EMPLOYEE;
```

Duplicate Elimination

- SQL does not automatically implement the duplicate elimination process of the Project operation
  - This is a departure from formal Relational Algebra
- To implement this, you need to use the DISTINCT keyword

```
SELECT DISTINCT firstname, surname, salary
from EMPLOYEE;
```

Select and Project

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
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Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

$$\sigma_{(\text{Dno}=4 \text{ AND } \text{Salary}>25000) \text{ OR } (\text{Dno}=5 \text{ AND } \text{Salary}>30000)}(\text{EMPLOYEE})$$

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5

Select and Project

EMPLOYEE

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James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

$\pi_{\text{Lname, Fname, Salary}}(\text{EMPLOYEE})$

Lname	Fname	Salary
Smith	John	30000
Wong	Franklin	40000
Zelaya	Alicia	25000
Wallace	Jennifer	43000
Narayan	Ramesh	38000
English	Joyce	25000
Jabbar	Ahmad	25000
Borg	James	55000

Select and Project

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
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James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

$$\pi_{\text{Sex, Salary}}(\text{EMPLOYEE})$$

Sex	Salary
M	30000
M	40000
F	25000
F	43000
M	38000
M	25000
M	55000

Combining Select and Project

- Complex queries often need to use combinations of Select and Project operations
- This can be achieved in two ways:
  - Nesting of operations in a single relational algebra expression
  - One operation at a time using intermediate result relations

Nesting Operations

- If we want a list of the names and salaries of all employees who earn more than €25,000 and work in the administration department
- This would require two operations
  - $\sigma_{(\text{Dno}=4 \text{ AND } \text{Salary}>25000)}(\text{EMPLOYEE})$
  - $\pi_{\text{Fname, Lname, Salary}}(\text{EMPLOYEE})$
- However, we can achieve the same result in a single relational algebra expression by nesting

$$\pi_{\text{Fname, Lname, Salary}}(\sigma_{(\text{Dno}=4 \text{ AND } \text{Salary}>25000)}(\text{EMPLOYEE}))$$

Intermediate Relations

- Operations can be applied one at a time using intermediate relations to store the results
- All intermediate tables must be named so that they can be referred to:

$$EMPS \leftarrow \sigma_{(\text{Dno=4 AND Salary>25000})}(\text{EMPLOYEE})$$

$$RESULT \leftarrow \pi_{F\text{name, Lname, Salary}}(\text{EMPS})$$

- It can sometimes be simpler to break complex queries into a series in this manner

Combining Select and Project

- The Select and Project operations can be combined in the SQL SELECT statement
- Consider the following operations
  - $\sigma_{(\text{Dno}=4 \text{ AND } \text{Salary}>25000)}(\text{EMPLOYEE})$
  - $\pi_{\text{Fname, Lname, Salary}}(\text{EMPLOYEE})$
- These can be combined in the following SQL:

```
SELECT Fname, Lname, Salary
from EMPLOYEE
WHERE Dno = 4
AND Salary > 25,000;
```

Exercises 4.1

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
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James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	NULL

PROJECT

Pname	Pnumber	Plocation	Dnum
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
333445555	Theodore	M	1983-10-25	Son
333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

Find all Employees who earn more than 15,000

Get a list of names and addresses of all employees

Find all Employees who are born before 1960 and earn more than €45,000

Find the name, social security number and date of birth of all Employees who are female and work in the department number 4

Find the name of all dependants who were born after 1980

Set Operators

- Standard mathematical operations used to merge the elements of two Sets
  - Union
  - Intersection
  - Set Difference
- Binary Operations
  - each operation is applied to two sets

Set Operators

- To use these operations, two relations must be "union compatible"
  - they must be of the same number of attributes
  - each corresponding pair of attributes has the same domain
- Two relations $R(A_1, A_2, \ldots, A_n)$ and $S(B_1, B_2, \ldots, B_n)$ are said to be union compatible if:
  - they have the same degree n
  - $dom(A_i) = dom(B_i)$ for $1 \leq i \leq n$

Union

- Denoted by $R \cup S$
- The result of a *Union* operation is a new relation which contains all tuples that are either in R or S or in both R and S.
- Duplicate tuples are discarded
- Commutative operation
  - $R \cup S = S \cup R$

Intersection

- Denoted by $R \cap S$
- The result of an *Intersection* operation is a new relation which contains all tuples that are in both R and S.
- Commutative operation
  - $R \cap S = S \cap R$

Union and Intersection

- Can both be treated as *n-ary* operations
  - applicable to any number of relations
  - as they are *associative operations*
  - $R \cup (S \cup T) = (R \cup S) \cup T$
  - $R \cap (S \cap T) = (R \cap S) \cap T$

Difference

- Denoted by $R - S$.
- The result of a *Set Difference* (or *Minus*) operation is a new relation that includes all tuples that are in R but not in S.
- Not cummutative
  - $R - S \neq S - R$

STUDENT

Fn	Ln
Susan	Yao
Ramesh	Shah
Johnny	Kohler
Barbara	Jones
Amy	Ford
Jimmy	Wang
Ernest	Gilbert

INSTRUCTOR

Fname	Lname
John	Smith
Ricardo	Browne
Susan	Yao
Francis	Johnson
Ramesh	Shah

STUDENT ∪ INSTRUCTOR

Fn	Ln
Susan	Yao
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STUDENT – INSTRUCTOR

Fn	Ln
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Set Operators in SQL

- There are three SQL commands which correspond to these Set Operators
  - UNION - Union
  - INTERSECT - Intersection
  - EXCEPT - Set Difference
- Additionally, there are multi-set operators in SQL that do not eliminate duplicates
  - UNION ALL
  - INTERSECT ALL
  - EXCEPT ALL

Join

- Denoted by $R \bowtie_{\text{(join condition)}} S$
- Used to combine related tuples from two relations, into a single tuple
  - Important as it allows for the processing of relationships between relations
- Makes use of Foreign Keys and Referential Integrity constraints that have been defined

Join

- Consider two relations $R(A_1, A_2, \ldots, A_n)$ and $S(B_1, B_2, \ldots, B_m)$
- The result of $R \bowtie_{\text{(join condition)}} S$ is a new relation Q with:
  - $n + m$ attributes
  - $Q(A_1, A_2, \ldots, A_n, B_1, B_2, \ldots, B_m)$
  - a tuple for each combination of tuples (one from R and one from S) that satisfy the join condition

Join Condition

- The join condition is specified on attributes from both relations, R and S
- It is evaluated for every combination of tuples from the two relations
- Each tuple combination for which the the join condition is TRUE is included in the result relation as a single, combined tuple

Join

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

Suppose we want to return the name of the manager of each department

$$\text{DEPARTMENT} \bowtie_{\text{Mgr\_ssn} = \text{Ssn}} \text{EMPLOYEE}$$

Dname	Dnumber	Mgr_ssn	Mgr_start_date	Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Research	5	333445555	1988-05-22	Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Administration	4	987654321	1995-01-01	Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Headquarters	1	888665555	1981-06-19	James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

Join

- Can then be combined with a Project operation to only return the required attributes

Dname	Dnumber	Mgr_ssn	Mgr_start_date	Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
Research	5	333445555	1988-05-22	Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Administration	4	987654321	1995-01-01	Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Headquarters	1	888665555	1981-06-19	James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

$$\pi_{\text{Dname, Fname, Lname}} (\text{DEPARTMENT} \bowtie_{\text{Mgr\_ssn = Ssn}} \text{EMPLOYEE})$$

Dname	Fname	Lname
Research	Franklin	Wong
Administration	Jennifer	Wallace
Headquarters	James	Borg

Joins in SQL

EMPNO	NAME	JOB	DEPTNO
7856	MCNULTY	OFFICER	30
7710	DANIELS	LIEUTENANT	40
7992	GREGGS	DETECTIVE	10
7428	MORELAND	DETECTIVE	20

Foreign Key

Primary Key

DEPTNO	NAME	LOCATION
10	NARCOTICS	TOWER 221
20	HOMICIDE	CITY CENTER
30	MARINE	DOCKS
40	EVIDENCE	DOWNTOWN

Joins in SQL

```
SELECT employee.name, job, department.name
FROM employee, department
WHERE employee.deptno = department.deptno;
```

NAME	JOB	NAME
MCNULTY	OFFICER	MARINE
DANIELS	LIEUTENANT	EVIDENCE
GREGGS	DETECTIVE	NARCOTICS
MORELAND	DETECTIVE	HOMICIDE

Exercises 4.2

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
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James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

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DEPT_LOCATIONS

Dnumber	Dlocation
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4	Stafford
5	Bellaire
5	Sugarland
5	Houston

WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	NULL

PROJECT

Pname	Pnumber	Plocation	Dnum
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
333445555	Theodore	M	1983-10-25	Son
333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

Join the DEPARTMENT and PROJECT tables

Get a list of project names and locations and the name of the department they belong to

Find the name and location of all departments

Get a list of names, social security numbers and dependent names for all employees who have dependents

Get a list of the names and department names of all employees who were born in or after 1970

Answers Exercise 4.1

- $\sigma_{(\text{Salary}>15000)}(\text{EMPLOYEE})$
- $\pi_{\text{Fname, Lname, Address}}(\text{EMPLOYEE})$
- $\sigma_{(\text{Salary}>45000 \text{ AND } \text{Bdate} < 1960\text{-}01\text{-}01)}(\text{EMPLOYEE})$
- $\pi_{\text{Fname, Lname, Ssn,Bdate}}(\sigma_{(\text{Sex=F AND Dno=4})}(\text{EMPLOYEE}))$
- or

  $EMPS \leftarrow \sigma_{(\text{Sex=F AND Dno=4})}(\text{EMPLOYEE})$

  $\pi_{\text{Fname,Lname,Ssn,Bdate}}(\text{EMPS})$
- $\pi_{\text{Fname, Lname}}(\sigma_{(\text{Bdate} > 1980\text{-}12\text{-}31)}(\text{DEPENDENTS}))$

Answers Exercise 4.2

$$\text{DEPARTMENT} \bowtie_{\text{Dnumber = Dnum}} \text{PROJECT}$$

$$\pi_{\text{Pname, Plocation, Dname}} (\text{DEPARTMENT} \bowtie_{\text{Dnumber = Dnum}} \text{PROJECT})$$

$$\pi_{\text{Dname, Dlocation}} (\text{DEPARTMENT} \bowtie_{\text{Dnumber = Dnumber}} \text{DEPT\_LOCATIONS})$$

$$\pi_{\text{Fname, Lname, Dependent\_name}} (\text{EMPLOYEE} \bowtie_{\text{Ssn = Essn}} \text{DEPENDENT})$$

$$\pi_{\text{Fname, Lname, Dname}} (\sigma_{(\text{Bdate} \geq \text{1970-01-01})} (\text{EMPLOYEE} \bowtie_{\text{Dno = Dnumber}} \text{DEPARTMENT}))$$