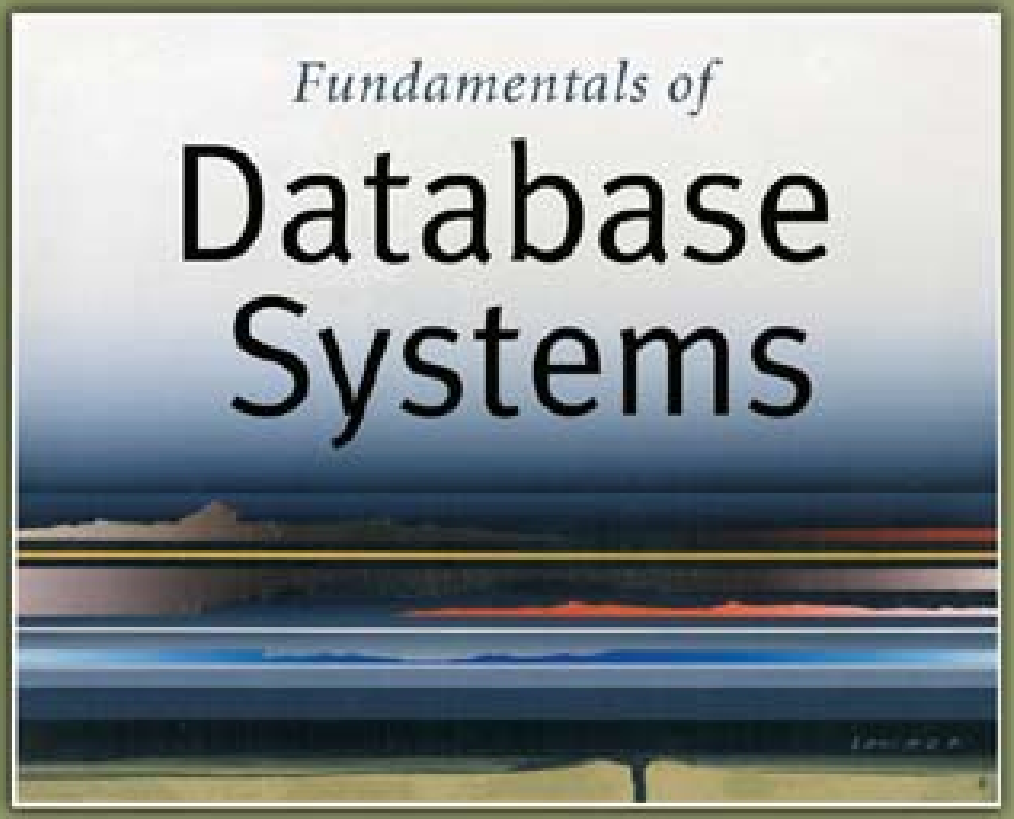
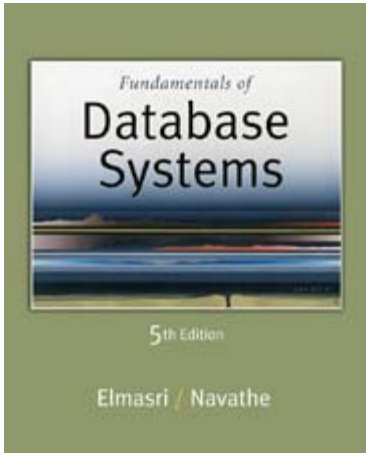


5th Edition

Elmasri / Navathe

Chapter 15

Algorithms for Query Processing and Optimization



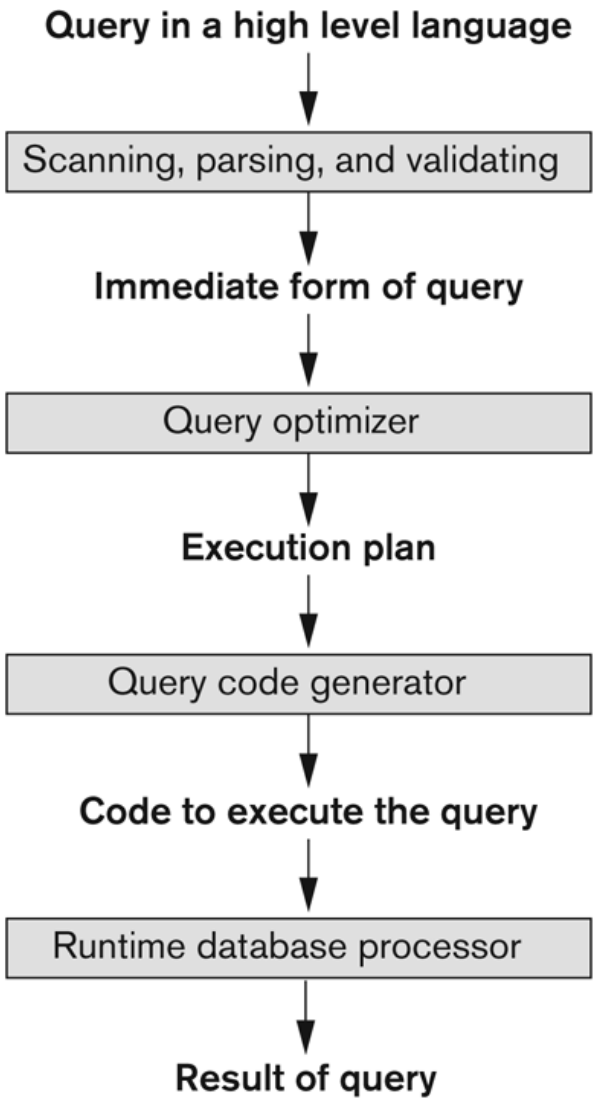


Figure 15.1
Typical steps when processing a high-level query.

Code can be:

Executed directly (interpreted mode)

Stored and executed later whenever needed (compiled mode)

```
set   i  ← 1;
      j  ← b;                  {size of the file in blocks}
      k  ← n_B;                {size of buffer in blocks}
      m  ← ⌈(j/k)⌉;

{Sort Phase}
while (i ≤ m)
do {
      read next k blocks of the file into the buffer or if there are less than k blocks
         remaining, then read in the remaining blocks;
      sort the records in the buffer and write as a temporary subfile;
      i  ← i + 1;
}

{Merge Phase: merge subfiles until only 1 remains}
set   i  ← 1;
      p  ← ⌈log_{k−1} m⌉;      {p is the number of passes for the merging phase}
      j  ← m;
while (i ≤ p)
do {
      n  ← 1;
      q  ← ⌈(j/(k−1))⌉;        {number of subfiles to write in this pass}
      while (n ≤ q)
      do {
            read next k−1 subfiles or remaining subfiles (from previous pass)
               one block at a time;
            merge and write as new subfile one block at a time;
            n ← n + 1;
      }
      j ← q;
      i ← i + 1;
}
```

Figure 15.2
Outline of the sort-merge algorithm for external sorting.

```
(a) sort the tuples in R on attribute A;     (* assume R has n tuples (records) *)
    sort the tuples in S on attribute B;     (* assume S has m tuples (records) *)
    set i ← 1, j ← 1;
    while (i ≤ n) and (j ≤ m)
    do {  if R(i)[A] > S(j)[B]
             then  set j ← j + 1
          elseif  R(i)[A] < S(j)[B]
             then  set i ← i + 1
          else  {  (* R(i)[A] = S(j)[B], so we output a matched tuple *)
                   output the combined tuple <R(i), S(j)> to T;

                   (* output other tuples that match R(i), if any *)
                   set l ← j + 1;
                   while (l ≤ m) and (R(i)[A] = S(l)[B])
                   do {  output the combined tuple <R(i), S(l)> to T;
                         set l ← l + 1
                   }

                   (* output other tuples that match S(j), if any *)
                   set k ← i + 1;
                   while (k ≤ n) and (R(k)[A] = S(j)[B])
                   do {  output the combined tuple <R(k), S(j)> to T;
                         set k ← k + 1
                   }
                   set i ← k, j ← l
          }
    }

(b) create a tuple t[<attribute list>] in T′ for each tuple t in R;
       (* T′ contains the projection results before duplicate elimination *)
    if <attribute list> includes a key of R
          then T ← T′
    else  {  sort the tuples in T′;
             set i ← 1, j ← 2;
             while i ≤ n
             do {  output the tuple T′[i] to T;
                   while T′[i] = T′[j] and j ≤ n do j ← j + 1;   (* eliminate duplicates *)
                   i ← j; j ← i + 1
             }
    }
    (* T contains the projection result after duplicate elimination *)
```

Figure 15.3
Implementing JOIN, PROJECT, UNION, INTERSECTION, and SET DIFFERENCE by using sort-merge, where R has n tuples and S has m tuples. (a) Implementing the operation $T \leftarrow R \bowtie_{A=B} S$. (b) Implementing the operation $T \leftarrow \pi_{<\text{attribute list}>}(R)$.

(c)
```
sort the tuples in R and S using the same unique sort attributes;
set i ← 1, j ← 1;
while (i ≤ n) and (j ≤ m)
do {  if R(i) > S(j)
        then  {  output S(j) to T;
                 set j ← j + 1
              }
      elseif R(i) < S(j)
        then  {  output R(i) to T;
                 set i ← i + 1
              }
      else set j ← j + 1    (* R(i)=S(j), so we skip one of the duplicate tuples *)
}
if (i ≤ n) then add tuples R(i) to R(n) to T;
if (j ≤ m) then add tuples S(j) to S(m) to T;
```

(d)
```
sort the tuples in R and S using the same unique sort attributes;
set i ← 1, j ← 1;
while (i ≤ n) and (j ≤ m)
do {  if R(i) > S(j)
        then  set j ← j + 1
      elseif R(i) < S(j)
        then  set i ← i + 1
      else  {  output R(j) to T;  (* R(i)=S(j), so we output the tuple *)
               set i ← i + 1, j ← j + 1
            }
}
```

(e)
```
sort the tuples in R and S using the same unique sort attributes;
set i ← 1, j ← 1;
while (i ≤ n) and (j ≤ m)
do {  if R(i) > S(j)
        then  set j ← j + 1
      elseif R(i) < S(j)
        then  {  output R(i) to T;   (* R(i) has no matching S(j), so output R(i) *)
                 set i ← i + 1
              }
      else  set i ← i + 1, j ← j + 1
}
if (i ≤ n) then add tuples R(i) to R(n) to T;
```

Figure 15.3 (continued)
Implementing JOIN, PROJECT, UNION, INTERSECTION, and SET DIFFERENCE by using sort-merge, where R has n tuples and S has m tuples. (c) Implementing the operation $T \leftarrow R \cup S$. (d) Implementing the operation $T \leftarrow R \cap S$. (e) Implementing the operation $T \leftarrow R - S$.

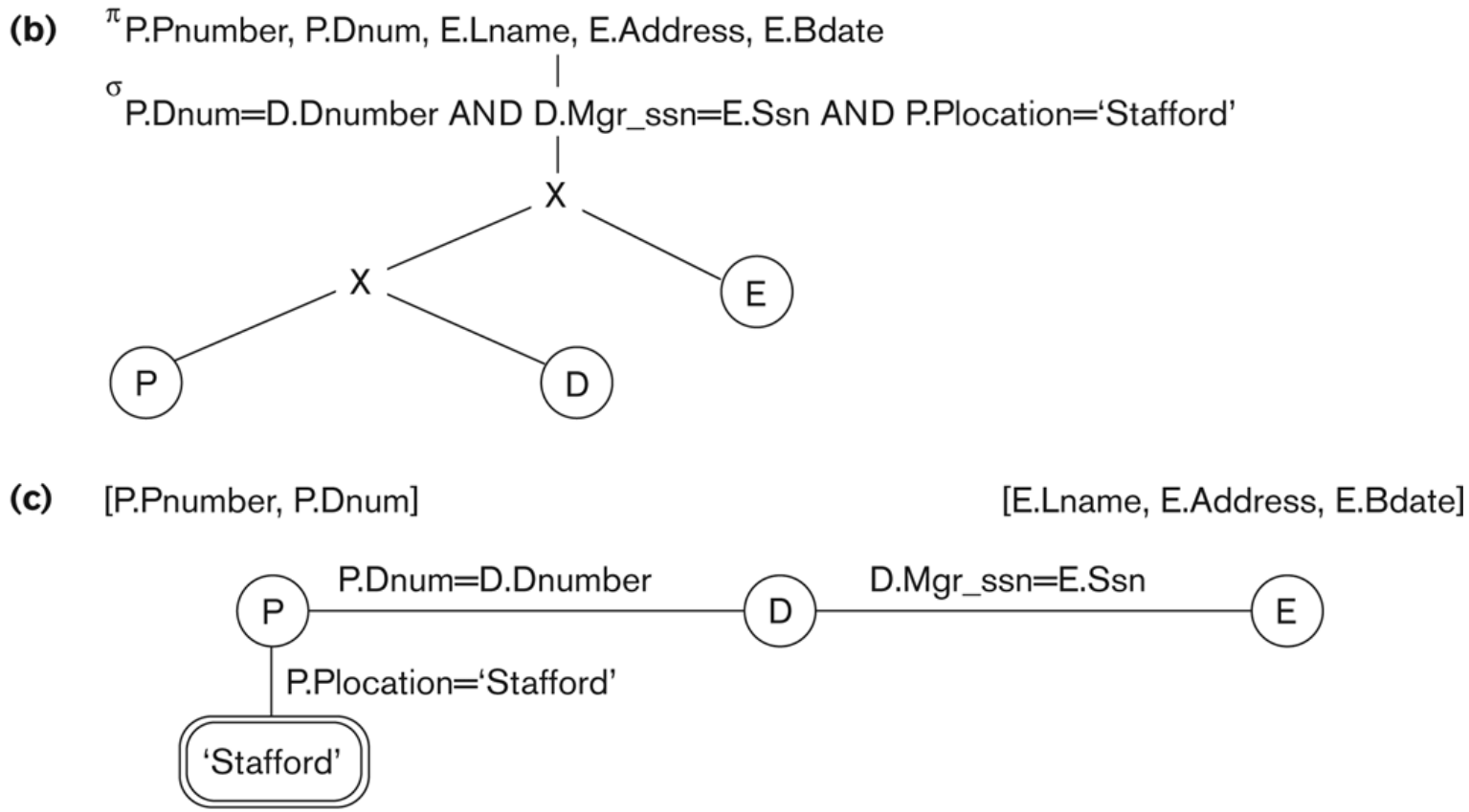


Figure 15.4
Two query trees for the query Q2. (a) Query tree corresponding to the relational algebra expression for Q2. (b) Initial (canonical) query tree for SQL query Q2. (c) Query graph for Q2.

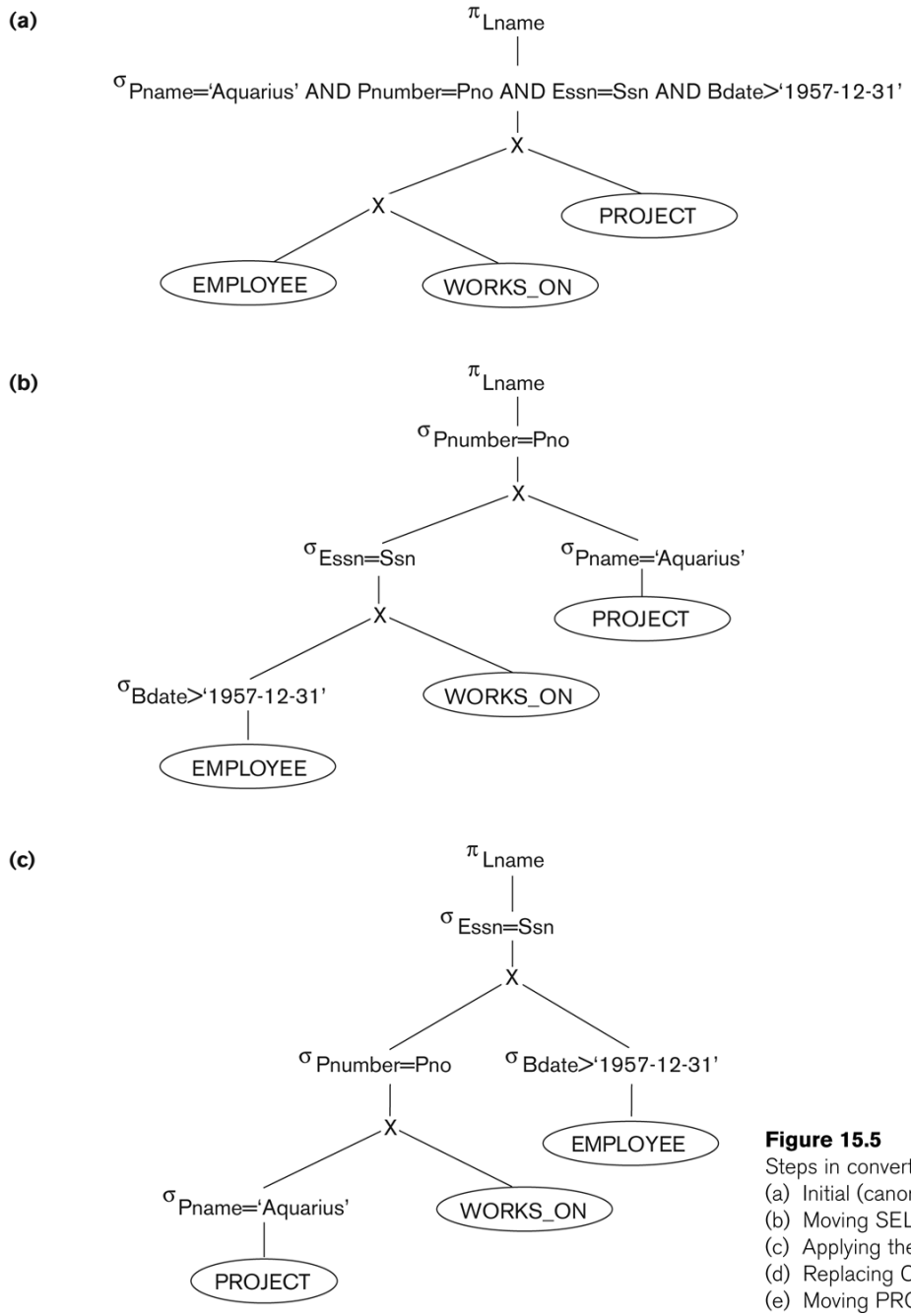
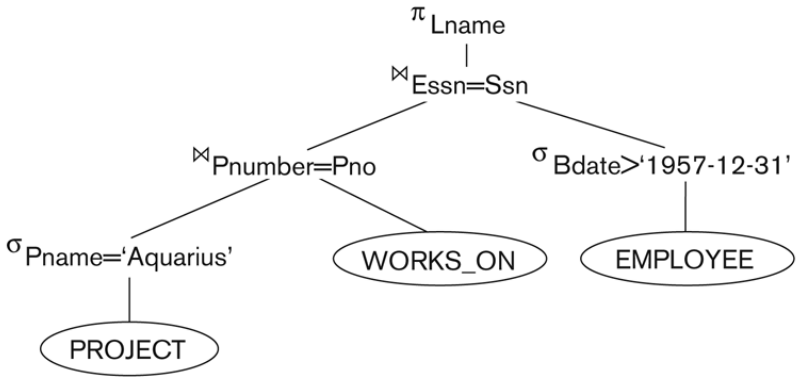
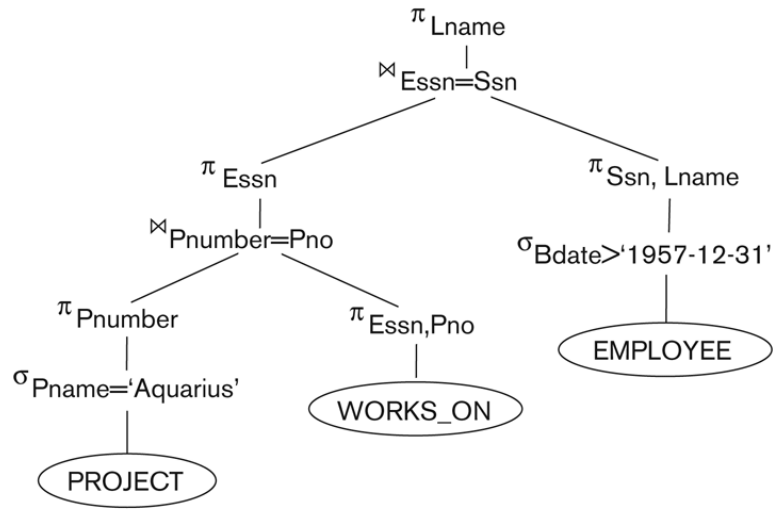


Figure 15.5
Steps in converting a query tree during heuristic optimization.
(a) Initial (canonical) query tree for SQL query Q.
(b) Moving SELECT operations down the query tree.
(c) Applying the more restrictive SELECT operation first.
(d) Replacing CARTESIAN PRODUCT and SELECT with JOIN operations.
(e) Moving PROJECT operations down the query tree.

(d)



(e)



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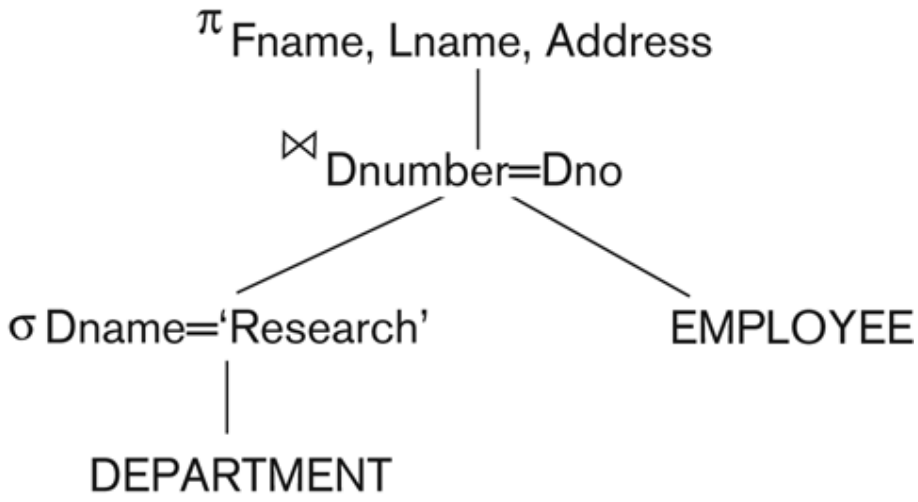

Figure 15.6
A query tree for query Q1.

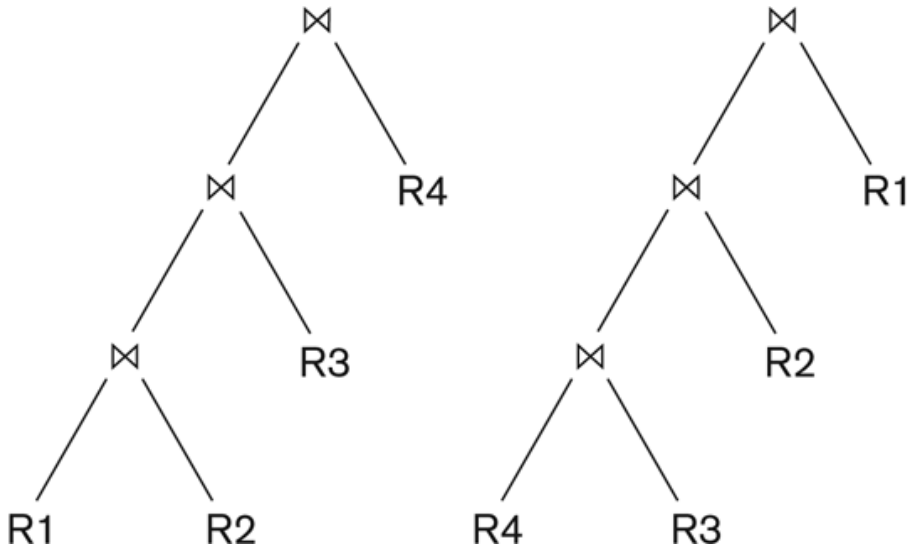

Figure 15.7
Two left-deep (JOIN) query trees.

Figure 15.8
Sample statistical information for relations in Q2. (a) Column information. (b) Table information. (c) Index information.

(a)

Table_name	Column_name	Num_distinct	Low_value	High_value
PROJECT	Plocation	200	1	200
PROJECT	Pnumber	2000	1	2000
PROJECT	Dnum	50	1	50
DEPARTMENT	Dnumber	50	1	50
DEPARTMENT	Mgr_ssn	50	1	50
EMPLOYEE	Ssn	10000	1	10000
EMPLOYEE	Dno	50	1	50
EMPLOYEE	Salary	500	1	500

(b)

Table_name	Num_rows	Blocks
PROJECT	2000	100
DEPARTMENT	50	5
EMPLOYEE	10000	2000

(c)

Index_name	Uniqueness	Blevel*	Leaf_blocks	Distinct_keys
PROJ_PLOC	NONUNIQUE	1	4	200
EMP_SSN	UNIQUE	1	50	10000
EMP_SAL	NONUNIQUE	1	50	500

*Blevel is the number of levels without the leaf level.