<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.4.4 Views in queries</td>
<td>135</td>
</tr>
<tr>
<td>4.5 Access control</td>
<td>136</td>
</tr>
<tr>
<td>4.5.1 Resources and privileges</td>
<td>136</td>
</tr>
<tr>
<td>4.5.2 Commands for granting and revoking privileges</td>
<td>137</td>
</tr>
<tr>
<td>4.6 Use of SQL in programming languages</td>
<td>138</td>
</tr>
<tr>
<td>4.6.1 Integration problems</td>
<td>139</td>
</tr>
<tr>
<td>4.6.2 Cursors</td>
<td>140</td>
</tr>
<tr>
<td>4.6.3 Dynamic SQL</td>
<td>142</td>
</tr>
<tr>
<td>4.6.4 Procedures</td>
<td>145</td>
</tr>
<tr>
<td>4.7 Summarizing examples</td>
<td>147</td>
</tr>
<tr>
<td>4.8 Bibliography</td>
<td>150</td>
</tr>
<tr>
<td>4.9 Exercises</td>
<td>150</td>
</tr>
<tr>
<td>Part II. Database design</td>
<td>155</td>
</tr>
<tr>
<td>5 Design techniques and models</td>
<td>157</td>
</tr>
<tr>
<td>5.1 The database design process</td>
<td>158</td>
</tr>
<tr>
<td>5.1.1 The life cycle of information systems</td>
<td>158</td>
</tr>
<tr>
<td>5.1.2 Methodologies for database design</td>
<td>160</td>
</tr>
<tr>
<td>5.2 The Entity-Relationship model</td>
<td>163</td>
</tr>
<tr>
<td>5.2.1 The basic constructs of the model</td>
<td>165</td>
</tr>
<tr>
<td>5.2.2 Other constructs of the model</td>
<td>170</td>
</tr>
<tr>
<td>5.2.3 Final overview of the E-R model</td>
<td>177</td>
</tr>
<tr>
<td>5.3 Documentation of E-R schemas</td>
<td>179</td>
</tr>
<tr>
<td>5.3.1 Business rules</td>
<td>180</td>
</tr>
<tr>
<td>5.3.2 Documentation techniques</td>
<td>182</td>
</tr>
<tr>
<td>5.4 Bibliography</td>
<td>183</td>
</tr>
<tr>
<td>5.5 Exercises</td>
<td>184</td>
</tr>
<tr>
<td>6 Conceptual design</td>
<td>189</td>
</tr>
<tr>
<td>6.1 Requirements collection and analysis</td>
<td>189</td>
</tr>
<tr>
<td>6.2 General criteria for data representation</td>
<td>194</td>
</tr>
<tr>
<td>6.3 Design strategies</td>
<td>196</td>
</tr>
<tr>
<td>6.3.1 Top-down strategy</td>
<td>196</td>
</tr>
<tr>
<td>6.3.2 Bottom-up strategy</td>
<td>198</td>
</tr>
<tr>
<td>6.3.3 Inside-out strategy</td>
<td>201</td>
</tr>
<tr>
<td>6.3.4 Mixed strategy</td>
<td>202</td>
</tr>
<tr>
<td>6.4 Quality of a conceptual schema</td>
<td>203</td>
</tr>
<tr>
<td>6.5 A comprehensive method for conceptual design</td>
<td>204</td>
</tr>
<tr>
<td>6.6 An example of conceptual design</td>
<td>205</td>
</tr>
<tr>
<td>6.7 CASE tools for database design</td>
<td>209</td>
</tr>
<tr>
<td>6.8 Bibliography</td>
<td>211</td>
</tr>
<tr>
<td>6.9 Exercises</td>
<td>211</td>
</tr>
<tr>
<td>7 Logical design</td>
<td>217</td>
</tr>
<tr>
<td>7.1 Performance analysis on E-R schemas</td>
<td>218</td>
</tr>
</tbody>
</table>
7.2 Restructuring of E-R schemas
  7.2.1 Analysis of redundancies
  7.2.2 Removing generalizations
  7.2.3 Partitioning and merging of entities and relationships
  7.2.4 Selection of primary identifiers
7.3 Translation into the relational model
  7.3.1 Entities and many-to-many relationships
  7.3.2 One-to-many relationships
  7.3.3 Entities with external identifiers
  7.3.4 One-to-one relationships
  7.3.5 Translation of a complex schema
  7.3.6 Summary tables
  7.3.7 Documentation of logical schemas
7.4 An example of logical design
  7.4.1 Restructuring phase
  7.4.2 Translation into the relational model
7.5 Logical design using CASE tools
7.6 Bibliography
7.7 Exercises
8 Normalization
  8.1 Redundancies and anomalies
  8.2 Functional dependencies
  8.3 Boyce–Codd normal form
    8.3.1 Definition of Boyce–Codd normal form
    8.3.2 Decomposition into Boyce–Codd normal form
  8.4 Decomposition properties
    8.4.1 Lossless decomposition
    8.4.2 Preservation of dependencies
    8.4.3 Qualities of decompositions
  8.5 Third normal form
    8.5.1 Definition of third normal form
    8.5.2 Decomposition into third normal form
    8.5.3 Other normalization techniques
  8.6 Database design and normalization
    8.6.1 Verification of normalization on entities
    8.6.2 Verification of normalization on relationships
    8.6.3 Further decomposition of relationships
    8.6.4 Further restructurings of conceptual schemas
  8.7 Bibliography
  8.8 Exercises

Part III. Database technology
9 Technology of a database server
  9.1 Definition of transactions
9.1.1 ACID properties of transactions 285
9.1.2 Transactions and system modules 287
9.2 Concurrency control 287
  9.2.1 Architecture of concurrency control 287
  9.2.2 Anomalies of concurrent transactions 288
  9.2.3 Concurrency control theory 290
  9.2.4 Lock management 301
  9.2.5 Deadlock management 305
9.3 Buffer management 307
  9.3.1 Architecture of the buffer manager 307
  9.3.2 Primitives for buffer management 308
  9.3.3 Buffer management policies 310
  9.3.4 Relationship between buffer manager and file system 310
9.4 Reliability control system 311
  9.4.1 Architecture of the reliability control system 312
  9.4.2 Log organization 313
  9.4.3 Transaction management 315
  9.4.4 Failure management 317
9.5 Physical access structures 320
  9.5.1 Architecture of the access manager 321
  9.5.2 Organization of tuples within pages 321
  9.5.3 Sequential structures 323
  9.5.4 Hash-based structures 325
  9.5.5 Tree structures 327
9.6 Query optimization 332
  9.6.1 Relation profiles 333
  9.6.2 Internal representation of queries 336
  9.6.3 Cost-based optimization 339
9.7 Physical database design 341
  9.7.1 Definition of indexes in SQL 343
9.8 Bibliography 343
9.9 Exercises 344
10 Distributed architectures 349
  10.1 Client-server architecture 351
  10.2 Distributed databases 353
    10.2.1 Applications of distributed databases 354
    10.2.2 Local independence and co-operation 355
    10.2.3 Data fragmentation and allocation 356
    10.2.4 Transparency levels 358
    10.2.5 Classification of transactions 360
  10.3 Technology of distributed databases 361
    10.3.1 Distributed query optimization 362
    10.3.2 Concurrency control 363
    10.3.3 Failures in distributed systems 368
10.4 Two-phase commit protocol
   10.4.1 New log records 369
   10.4.2 Basic protocol 370
   10.4.3 Recovery protocols 372
   10.4.4 Protocol optimization 374
   10.4.5 Other commit protocols 375
10.5 Interoperability
   10.5.1 Open Database Connectivity (ODBC) 377
   10.5.2 X-OPEN Distributed Transaction Processing (DTP) 378
10.6 Co-operation among pre-existing systems 381
10.7 Parallelism
   10.7.1 Inter-query and intra-query parallelism 384
   10.7.2 Parallelism and data fragmentation 385
   10.7.3 Speed-up and scale-up 386
   10.7.4 Transaction benchmarks 387
10.8 Replicated databases 388
   10.8.1 New functions of replication managers 390
10.9 Bibliography 391
10.10 Exercises 391

Part IV. Database evolution 395
11 Object databases 397
11.1 Object-Oriented databases (OODBMSs)
   11.1.1 Types 398
   11.1.2 Classes 399
   11.1.3 Methods 402
   11.1.4 Generalization hierarchies 404
   11.1.5 Persistence 408
   11.1.6 Redefinition of methods 411
   11.1.7 Refinement of properties and methods 414
   11.1.8 The object-oriented database manifesto 416
11.2 The ODMG standard for object-oriented databases 417
   11.2.1 Object Definition Language: ODL 417
   11.2.2 Object Query Language: OQL 419
11.3 Object-Relational databases (ORDBMSs)
   11.3.1 SQL-3 data model 423
   11.3.2 SQL-3 query language 427
   11.3.3 The third generation database manifesto 428
11.4 Multimedia databases 429
   11.4.1 Types of multimedia data 429
   11.4.2 Queries on multimedia data 430
   11.4.3 Document search 431
   11.4.4 Representation of spatial data 432
11.5 Technological extensions for object-oriented databases 434
### 14  Databases and the World Wide Web 489

14.1  The Internet and the World Wide Web 490
- 14.1.1 The Internet 490
- 14.1.2 The World Wide Web 491
- 14.1.3 HTML 492
- 14.1.4 HTTP 494
- 14.1.5 Gateways 494

14.2  Information systems on the Web 495
- 14.2.1 Publication and consultation on the Web 496
- 14.2.2 Transactions on the Web 496
- 14.2.3 Electronic commerce and other new applications 497

14.3  Design of data-intensive Web sites 498
- 14.3.1 A logical model for data-intensive hypertexts 499
- 14.3.2 Levels of representation in Web hypertexts 502
- 14.3.3 Design principles for a data-intensive Web site 505

14.4  Techniques and tools for database access through the Web 508
- 14.4.1 Database access through CGI programs 508
- 14.4.2 Development tools 510
- 14.4.3 Shortcomings of the CGI protocol 511
- 14.4.4 Simulating long connections for transactions 511
- 14.4.5 Server-based alternatives to the CGI approach 512
- 14.4.6 Client-based alternatives to the CGI approach 514

14.5  Bibliography 516

14.6  Exercises 517

---

### Part V. Appendices & Bibliography 519

**Appendix A  Microsoft Access** 521

A.1  System characteristics 522

A.2  Definition of tables 523
- A.2.1 Specification of join paths 528
- A.2.2 Populating the table 529

A.3  Query definition 530
- A.3.1 Query By Example 530
- A.3.2 The SQL interpreter 536

A.4  Forms and reports 538

A.5  The definition of macros 539

**Appendix B  DB2 Universal Database** 543

B.1  DB2 overview 544
- B.1.1 Versions of the system 544
- B.1.2 Instances and schemas of DB2 545
- B.1.3 Interaction with DB2 545

B.2  Database management with DB2 546
- B.2.1 Interactive tools 546
- B.2.2 Application programs 551
B.3  Advanced features of DB2  554
  B.3.1  Extension of SQL for queries  554
  B.3.2  Object-oriented features of DB2  558

**Appendix C  Oracle PL/SQL**  565
  C.1  Tools architecture of Oracle  565
  C.2  Base domains  567
  C.3  The object-relational extension of Oracle  569
  C.4  PL/SQL language  572
    C.4.1  Execution of PL/SQL in a client-server environment  573
    C.4.2  Declarations of variables and cursors  574
    C.4.3  Control structures  576
    C.4.4  Management of exceptions  578
    C.4.5  Procedures  580
    C.4.6  Packages  585

**Bibliography**  587

**Index**  593