CONTENTS

PART 1: BASIC CONCEPTS

Chapter 1 Databases and Database Users 2

1.1 Introduction 4
1.2 An Example 5
1.3 Characteristics of the Database Approach 8
1.4 Actors on the Scene 12
1.5 Workers behind the Scene 13
1.6 Advantages of Using a DBMS 14
1.7 Implications of the Database Approach 18
1.8 When Not to Use a DBMS 19
1.9 Summary 19
Review Questions 20
Exercises 21
Selected Bibliography 21

Chapter 2 Database System Concepts and Architecture 23

2.1 Data Models, Schemas, and Instances 24
2.2 DBMS Architecture and Data Independence 27
2.3 Database Languages and Interfaces 30
2.4 The Database System Environment 32

2.5 Classification of Database Management Systems 35
2.6 Summary 37
Review Questions 38
Exercises 39
Selected Bibliography 39

Chapter 3 Data Modeling Using the Entity-Relationship Model 41

3.1 Using High-Level Conceptual Data Models for Database Design 42
3.2 An Example Database Application 44
3.3 Entity Types, Entity Sets, Attributes, and Keys 45
3.4 Relationships, Relationship Types, Roles, and Structural Constraints 52
3.5 Weak Entity Types 59
3.6 Refining the ER Design for the COMPANY Database 60
3.7 ER Diagrams, Naming Conventions, and Design Issues 61
3.8 Summary 66
Review Questions 67
Exercises 67
Selected Bibliography 72

Chapter 4 Enhanced Entity-Relationship and Object Modeling 73

4.1 Subclasses, Superclasses, and Inheritance 74
4.2 Specialization and Generalization 76
4.3 Constraints and Characteristics of Specialization and Generalization 80
4.4 Modeling of UNION Types Using Categories 86
4.5 An Example UNIVERSITY EER Schema and Formal Definitions for the EER Model 90
4.6 Conceptual Object Modeling Using UML Class Diagrams 93

4.7 Relationship Types of Degree Higher Than Two 95
4.8 Data Abstraction and Knowledge Representation Concepts 100
4.9 Summary 105
Review Questions 105
Exercises 106
Selected Bibliography 110

Chapter 5 Record Storage and Primary File Organizations 113

5.1 Introduction 114
5.2 Secondary Storage Devices 117
5.3 Parallelizing Disk Access Using RAID Technology 122
5.4 Buffering of Blocks 127
5.5 Placing File Records on Disk 128
5.6 Operations on Files 133
5.7 Files of Unordered Records (Heap Files) 135
5.8 Files of Ordered Records (Sorted Files) 136
5.9 Hashing Techniques 139
5.10 Other Primary File Organizations 148
5.11 Summary 149
Review Questions 149
Exercises 150
Selected Bibliography 153

Chapter 6 Index Structures for Files 155

6.1 Types of Single-Level Ordered Indexe 156
6.2 Multilevel Indexes 166
6.3 Dynamic Multilevel Indexes Using B-Trees and B^+-Trees 169
6.4 Indexes on Multiple Keys 183
6.5 Other Types of Indexes 186
6.6 Summary 187
Review Questions 188

Exercises 188
Selected Bibliography 190

PART 2: RELATIONAL MODEL, LANGUAGES, AND SYSTEMS 193

Chapter 7 · The Relational Data Model, Relational Constraints, and the Relational Algebra 195

7.1 Relational Model Concepts 196
7.2 Relational Constraints and Relational Database Schemas 202
7.3 Update Operations and Dealing with Constraint Violations 209
7.4 Basic Relational Algebra Operations 211
7.5 Additional Relational Operations 226
7.6 Examples of Queries in Relational Algebra 230
7.7 Summary 232
Review Questions 233
Exercises 235
Selected Bibliography 240

Chapter 8 SQL–The Relational Database Standard 243

8.1 Data Definition, Constraints, and Schema Changes in SQL2 245
8.2 Basic Queries in SQL 251
8.3 More Complex SQL Queries 261
8.4 Insert, Delete, and Update Statements in SQL 275
8.5 Views (Virtual Tables) in SQL 278
8.6 Specifying General Constraints as Assertion 282
8.7 Additional Features of SQL 283
8.8 Summary 284

Review Questions 284
Exercises 286
Selected Bibliography 288

Chapter 9 ER- and EER-to-Relational Mapping, and Other Relational Languages 289

9.1 Relational Database Design Using ER-to-Relational Mapping 290
9.2 Mapping EER Model Concepts to Relations 295
9.3 The Tuple Relational Calculus 299
9.4 The Domain Relational Calculus 308
9.5 Overview of the QBE Language 310
9.6 Summary 317
Review Questions 318
Exercises 319
Selected Bibliography 320

Chapter 10 Examples of Relational Database Management Systems: Oracle and Microsoft Access 323

10.1 Relational Database Management Systems: A Historical Perspective 324
10.2 The Basic Structure of the Oracle System 325
10.3 Database Structure and Its Manipulation in Oracle 329
10.4 Storage Organization in Oracle 333
10.5 Programming Oracle Applications 337
10.6 Oracle Tools 343
10.7 An Overview of Microsoft Access 344
10.8 Features and Functionality of Access 351
10.9 Summary 355
Selected Bibliography 355

PART 3: OBJECT-ORIENTED AND EXTENDED RELATIONAL DATABASE TECHNOLOGY 357

Chapter 11 Concepts for Object-Oriented Databases 359

11.1 Overview of Object-Oriented Concepts 361
11.2 Object Identity, Object Structure, and Type Constructors 363
11.3 Encapsulation of Operations, Methods, and Persistence 369
11.4 Type Hierarchies and Inheritance 374
11.5 Complex Objects 377
11.6 Other Object-Oriented Concepts 379
11.7 Summary 382
Review Questions 383
Exercises 384
Selected Bibliography 384

Chapter 12 Object Database Standards, Languages, and Design 385

12.1 Overview of the Object Model of ODMG 386
12.2 The Object Definition Language 399
12.3 The Object Query Language 404
12.4 Overview of the C++ Language Binding 413
12.5 Object Database Conceptual Design 414
12.6 Examples of ODBMSs 417
12.7 Overview of the CORBA Standard for Distributed Objects 428
12.8 Summary 431
Review Questions 432
Exercises 432
Selected Bibliography 433

Chapter 13 Object Relational and Extended Relational Database Systems 435

13.1 Evolution and Current Trends of Database Technology 436
13.2 The Informix Universal Server 438
13.3 Object-Relational Features of Oracle 8 448
13.4 An Overview of SQL3 451
13.5 Implementation and Related Issues for Extended Type Systems 458
13.6 The Nested Relational Data Model 459
13.7 Summary 461
Selected Bibliography 462

PART 4: DATABASE DESIGN THEORY AND METHODOLOGY 463

Chapter 14 Functional Dependencies and Normalization for Relational Databases 465

14.1 Informal Design Guidelines for Relation Schemas 467
14.2 Functional Dependencies 476
14.3 Normal Forms Based on Primary Keys 483
14.4 General Definitions of Second and Third Normal Forms 490
14.5 Boyce-Codd Normal Form 493
14.6 Summary 496
Review Questions 496
Exercises 497
Selected Bibliography 500

Chapter 15 Relational Database Design Algorithms and Further Dependencies 501

15.1 Algorithms for Relational Database Schema Design 502

15.2 Multivalued Dependencies and Fourth Normal Form 514
15.3 Join Dependencies and Fifth Normal Form 519
15.4 Inclusion Dependencies 520
15.5 Other Dependencies and Normal Forms 521
15.6 Summary 523
Review Questions 524
Exercises 524
Selected Bibliography 525

Chapter 16 Practical Database Design and Tuning 527

16.1 The Role of Information Systems in Organizations 528
16.2 The Database Design Process 532
16.3 Physical Database Design in Relational Databases 551
16.4 An Overview of Database Tuning in Relational Systems 554
16.5 Automated Design Tools 560
16.6 Summary 563
Review Questions 564
Selected Bibliography 565

PART 5: SYSTEM IMPLEMENTATION TECHNIQUES 568

Chapter 17 Database System Architectures and the System Catalog 569

17.1 System Architectures for DBMSs 570
17.2 Catalogs for Relational DBMSs 573
17.3 System Catalog Information in ORACLE 577
17.4 Other Catalog Information Accessed by DBMS Software Modules 581
17.5 Data Dictionary and Data Repository Systems 582
17.6 Summary 583

Review Questions 584
Exercises 584
Selected Bibliography 585

Chapter 18 · Query Processing and Optimization 585

18.1 Translating SQL Queries into Relational Algebra 587
18.2 Basic Algorithms for Executing Query Operations 588
18.3 Using Heuristics in Query Optimization 604
18.4 Using Selectivity and Cost Estimates in Query Optimization 615
18.5 Overview of Query Optimization in ORACLE 624
18.6 Semantic Query Optimization 625
18.7 Summary 626
Review Questions 626
Exercises 627
Selected Bibliography 628

Chapter 19 · Transaction Processing Concepts 629

19.1 Introduction to Transaction Processing 630
19.2 Transaction and System Concepts 637
19.3 Desirable Properties of Transactions 640
19.4 Schedules and Recoverability 641
19.5 Serializability of Schedules 644
19.6 Transaction Support in SQL 654
19.7 Summary 656
Review Questions 657
Exercises 657
Selected Bibliography 659

Chapter 20 · Concurrency Control Techniques 661

20.1 Locking Techniques for Concurrency Control 662
20.2 Concurrency Control Based on Timestamp Ordering 672

20.3 Multiversion Concurrency Control Techniques 674
20.4 Validation (Optimistic) Concurrency Control Techniques 677
20.5 Granularity of Data Items and Multiple Granularity Locking 678
20.6 Using Locks for Concurrency Control in Indexes 683
20.7 Some Other Concurrency Control Issues 684
20.8 Summary 685
Review Questions 686
Exercises 687
Selected Bibliography 687

Chapter 21 Database Recovery Techniques 689

21.1 Recovery Concepts 690
21.2 Recovery Techniques Based on Deferred Update 696
21.3 Recovery Techniques Based on Immediate Update 701
21.4 Shadow Paging 702
21.5 The ARIES Recovery Algorithm 704
21.6 Recovery in Multidatabase Systems 708
21.7 Database Backup and Recovery from Catastrophic Failures 709
21.8 Summary 709
Review Questions 710
Exercises 711
Selected Bibliography 713

Chapter 22 Database Security and Authorization 715

22.1 Introduction to Database Security Issues 715
22.2 Discretionary Access Control Based on Granting/Revoking of Privileges 718
22.3 Mandatory Access Control for Multilevel Security 723
22.4 Introduction to Statistical Database Security 726

22.5 Summary 728
Review Questions 728
Exercises 729
Selected Bibliography 729

PART 6: ADVANCED DATABASE CONCEPTS & EMERGING APPLICATION 731

Chapter 23 Enhanced Data Models for Advanced Applications 733

23.1 Active Database Concepts 734
23.2 Temporal Database Concepts 744
23.3 Spatial and Multimedia Databases 757
23.4 Summary 760
Review Questions 761
Exercises 762
Selected Bibliography 763

Chapter 24 Distributed Databases and Client-Server Architecture 765

24.1 Distributed Database Concepts 766
24.2 Data Fragmentation, Replication, and Allocation Techniques for Distributed Database Design 771
24.3 Types of Distributed Database Systems 778
24.4 Query Processing in Distributed Databases 781
24.5 Overview of Concurrency Control and Recovery in Distributed Databases 786
24.6 An Overview of Client-Server Architecture and Its Relationship to Distributed Databases 789
24.7 Distributed Databases in Oracle 791
24.8 Future Prospects of Client-Server Technology 793
24.9 Summary 795

Review Questions 795
Exercises 796
Selected Bibliography 798

Chapter 25 Deductive Databases 801

25.1 Introduction to Deductive Databases 802
25.2 Prolog/Datalog Notation 803
25.3 Interpretation of Rules 808
25.4 Basic Inference Mechanisms for Logic Programs 810
25.5 Datalog Programs and Their Evaluation 813
25.6 Deductive Database Systems 827
25.7 Deductive Object-Oriented Databases 832
25.8 Applications of Commercial Deductive Database Systems 834
25.9 Summary 835
Exercises 836
Selected Bibliography 839

Chapter 26 Data Warehousing and Data Mining 841

26.1 Data Warehousing 842
26.2 Data Mining 855
26.3 Summary 870
Review Exercises 871
Selected Bibliography 872

Chapter 27 Emerging Database Technologies and Applications 73

27.1 Databases on the World Wide Web 874
27.2 Multimedia Databases 880
27.3 Mobile Databases 886
27.4 Geographic Information Systems 891
27.5 Genome Data Management 898
27.6 Digital Libraries 905

Appendix A Alternative Diagrammatic Notations 909

Appendix B Parameters of Disks 913

Appendix C An Overview of the Network Data Model 917

Appendix D An Overview of the Hierarchical Data Model 941

Selected Bibliography B-1

Index I-1