**Part 1: Introduction to Databases**

**Chapter 1 Databases and Database Users    3**

    1.1 Introduction    4

    1.2 An Example    6

    1.3 Characteristics of the Database Approach    9

    1.4 Actors on the Scene    14

    1.5 Workers behind the Scene    16

    1.6 Advantages of Using the DBMS Approach    17

    1.7 A Brief History of Database Applications    23

    1.8 When Not to Use a DBMS    26

    1.9 Summary    27

    Review Questions    27

    Exercises    28

    Selected Bibliography    28

**Chapter 2 Database System Concepts and Architecture    29**

    2.1 Data Models, Schemas, and Instances     30

    2.2 Three-Schema Architecture and Data Independence    33

    2.3 Database Languages and Interfaces    36

    2.4 The Database System Environment    40

    2.5 Centralized and Client/Server Architectures for DBMSs    44

    2.6 Classification of Database Management Systems    49

    2.7 Summary    52

    Review Questions    53

    Exercises    54

    Selected Bibliography    55

**Part 2: Relational Data Model and SQL**

**Chapter 3 The Relational Data Model and Relational Database Constraints    59**

    3.1 Relational Model Concepts    60

    3.2 Relational Model Constraints and Relational Database Schemas    67

    3.3 Update Operations, Transactions, and Dealing with Constraint Violations    75

    3.4 Summary    79

    Review Questions    80

    Exercises    80

    Selected Bibliography    85

**Chapter 4 Basic SQL    87**

    4.1 SQL Data Definition and Data Types    89

    4.2 Specifying Constraints in SQL    94

    4.3 Basic Retrieval Queries in SQL    97

    4.4 INSERT, DELETE, and UPDATE Statements in SQL    107

    4.5 Additional Features of SQL    110

    4.6 Summary    111

    Review Questions    112

    Exercises    112

    Selected Bibliography    114

**Chapter 5 More SQL: Complex Queries, Triggers, Views, and Schema Modification    115**

    5.1 More Complex SQL Retrieval Queries    115

    5.2 Specifying Constraints as Assertions and Actions as Triggers    131

    5.3 Views (Virtual Tables) in SQL    133

    5.4 Schema Change Statements in SQL    137

    5.5 Summary    139

    Review Questions    141

    Exercises    141

    Selected Bibliography    143

**Chapter** **6 The Relational Algebra and Relational Calculus    145**

    6.1 Unary Relational Operations: SELECT and PROJECT    147

    6.2 Relational Algebra Operations from Set Theory    152

    6.3 Binary Relational Operations: JOIN and DIVISION    157

    6.4 Additional Relational Operations    165

    6.5 Examples of Queries in Relational Algebra    171

    6.6 The Tuple Relational Calculus    174

    6.7 The Domain Relational Calculus    183

    6.8 Summary    185

    Review Questions    186

    Exercises    187

    Laboratory Exercises    192

    Selected Bibliography    194

**Part 3: Conceptual Modeling and Database Design**

**Chapter 7 Data Modeling Using the Entity-Relationship (ER) Model    199**

    7.1 Using High-Level Conceptual Data Models for Database Design    200

    7.2 A Sample Database Application    202

    7.3 Entity Types, Entity Sets, Attributes, and Keys    203

    7.4 Relationship Types, Relationship Sets, Roles, and Structural Constraints    212

    7.5 Weak Entity Types    219

    7.6 Refining the ER Design for the COMPANY Database    220

    7.7 ER Diagrams, Naming Conventions, and Design Issues    221

    7.8 Example of Other Notation: UML Class Diagrams    226

    7.9 Relationship Types of Degree Higher than Two    228

    7.10 Summary    232

    Review Questions    234

    Exercises    234

    Laboratory Exercises    241

    Selected Bibliography    243

**Chapter** **8 The Enhanced Entity-Relationship (EER) Model    245**

    8.1 Subclasses, Superclasses, and Inheritance    246

    8.2 Specialization and Generalization    248

    8.3 Constraints and Characteristics of Specialization and Generalization Hierarchies    251

    8.4 Modeling of UNION Types Using Categories    258

    8.5 A Sample UNIVERSITY EER Schema, Design Choices, and Formal Definitions    260

    8.6 Example of Other Notation: Representing Specialization and Generalization in UML Class Diagrams    265

    8.7 Data Abstraction, Knowledge Representation, and Ontology Concepts    267

    8.8 Summary    273

    Review Questions    273

    Exercises    274

    Laboratory Exercises    281

    Selected Bibliography    284

**Chapter 9 Relational Database Design by ERand EER-to-Relational Mapping    285**

    9.1 Relational Database Design Using ER-to-Relational Mapping    286

    9.2 Mapping EER Model Constructs to Relations    294

    9.3 Summary    299

    Review Questions    299

    Exercises    299

    Laboratory Exercises    301

    Selected Bibliography    302

**Chapter 10 Practical Database Design Methodology and Use of UML Diagrams    303**

    10.1 The Role of Information Systems in Organizations    304

    10.2 The Database Design and Implementation Process    309

    10.3 Use of UML Diagrams as an Aid to Database Design Specification    328

    10.4 Rational Rose: A UML-Based Design Tool    337

    10.5 Automated Database Design Tools    342

    10.6 Summary    345

    Review Questions    347

    Selected Bibliography    348

**Part 4: Object, Object-Relational, and XML Models**

**Chapter** **11 Object and Object-Relational Databases    353**

    11.1 Overview of Object Database Concepts    355

    11.2 Object-Relational Features: Object Database Extensions to SQL    369

    11.3 The ODMG Object Model and the Object Definition Language ODL    376

    11.4 Object Database Conceptual Design    395

    11.5 The Object Query Language OQL    398

    11.6 Overview of the C++ Language Binding in the ODMG Standard    407

    11.7 Summary    408

    Review Questions    409

    Exercises    411

    Selected Bibliography    412

**Chapter** **12 XML: Extensible Markup Language    415**

    12.1 Structured, Semistructured, and Unstructured Data    416

    12.2 XML Hierarchical (Tree) Data Model    420

    12.3 XML Documents, DTD, and XML Schema    423

    12.4 Storing and Extracting XML Documents from Databases    431

    12.5 XML Languages    432

    12.6 Extracting XML Documents from Relational Databases    436

    12.7 Summary    442

    Review Questions    442

    Exercises    443

    Selected Bibliography    443

**Part 5: Database Programming Techniques**

**Chapter** **13 Introduction to SQL Programming Techniques 447**

    13.1 Database Programming: Techniques and Issues    448

    13.2 Embedded SQL, Dynamic SQL, and SQLJ    451

    13.3 Database Programming with Function Calls: SQL/CLI and JDBC    464

    13.4 Database Stored Procedures and SQL/PSM    473

    13.5 Comparing the Three Approaches    476

    13.6 Summary    477

    Review Questions    478

    Exercises    478

    Selected Bibliography    479

**Chapter** **14 Web Database Programming Using PHP    481**

    14.1 A Simple PHP Example    482

    14.2 Overview of Basic Features of PHP    484

    14.3 Overview of PHP Database Programming    491

    14.4 Summary    496

    Review Questions    496

    Exercises    497

    Selected Bibliography    497

**Part 6: Database Normalization Theory**

**Chapter** **15 Basics of Functional Dependencies and Normalization for Relational Databases    501**

    15.1 Informal Design Guidelines for Relation Schemas    503

    15.2 Functional Dependencies    513

    15.3 Normal Forms Based on Primary Keys    516

    15.4 General Definitions of Second and Third Normal Forms    525

    15.5 Boyce-Codd Normal Form    529

    15.6 Multivalued Dependency and Fourth Normal Form    531

    15.7 Join Dependencies and Fifth Normal Form    534

    15.8 Summary    535

    Review Questions    536

    Exercises    537

    Laboratory Exercises    542

    Selected Bibliography    542

**Chapter** **16 Relational Database Design Algorithms and Further Dependencies    543**

    16.1 Further Topics in Functional Dependencies: Inference Rules, Equivalence, and Minimal Cover    545

    16.2 Properties of Relational Decompositions    551

    16.3 Algorithms for Relational Database Schema Design    557

    16.4 About Nulls, Dangling Tuples, and Alternative Relational Designs    563

    16.5 Further Discussion of Multivalued Dependencies and 4NF    567

    16.6 Other Dependencies and Normal Forms    571

    16.7 Summary    575

    Review Questions    576

    Exercises    576

    Laboratory Exercises    578

    Selected Bibliography    579

**Part 7: File Structures, Indexing, and Hashing**

**Chapter** **17 Disk Storage, Basic File Structures, and Hashing    583**

    17.1 Introduction    584

    17.2 Secondary Storage Devices    587

    17.3 Buffering of Blocks    593

    17.4 Placing File Records on Disk    594

    17.5 Operations on Files    599

    17.6 Files of Unordered Records (Heap Files)    601

    17.7 Files of Ordered Records (Sorted Files)    603

    17.8 Hashing Techniques    606

    17.9 Other Primary File Organizations    616

    17.10 Parallelizing Disk Access Using RAID Technology    617

    17.11 New Storage Systems    621

    17.12 Summary    624

    Review Questions    625

    Exercises    626

    Selected Bibliography    630

**Chapter** **18 Indexing Structures for Files    631**

    18.1 Types of Single-Level Ordered Indexes    632

    18.2 Multilevel Indexes    643

    18.3 Dynamic Multilevel Indexes Using B-Trees and B+-Trees    646

    18.4 Indexes on Multiple Keys    660

    18.5 Other Types of Indexes    663

    18.6 Some General Issues Concerning Indexing    668

    18.7 Summary    670

    Review Questions    671

    Exercises    672

    Selected Bibliography    674

**Part 8: Query Processing, Optimization, and Database Tuning**

**Chapter 19 Algorithms for Query Processing and Optimization    679**

    19.1 Translating SQL Queries into Relational Algebra    681

    19.2 Algorithms for External Sorting    682

    19.3 Algorithms for SELECT and JOIN Operations    685

    19.4 Algorithms for PROJECT and Set Operations    696

    19.5 Implementing Aggregate Operations and OUTER JOINs    698

    19.6 Combining Operations Using Pipelining    700

    19.7 Using Heuristics in Query Optimization    700

    19.8 Using Selectivity and Cost Estimates in Query Optimization    710

    19.9 Overview of Query Optimization in Oracle    721

    19.10 Semantic Query Optimization    722

    19.11 Summary    723

    Review Questions    723

    Exercises    724

    Selected Bibliography    725

**Chapter** **20 Physical Database Design and Tuning    727**

    20.1 Physical Database Design in Relational Databases    727

    20.2 An Overview of Database Tuning in Relational Systems    733

    20.3 Summary    739

    Review Questions    739

    Selected Bibliography    740

**Part 9: Transaction Processing, Concurrency Control, and Recovery**

**Chapter 21 Introduction to Transaction Processing Concepts and Theory    743**

    21.1 Introduction to Transaction Processing    744

    21.2 Transaction and System Concepts    751

    21.3 Desirable Properties of Transactions    754

    21.4 Characterizing Schedules Based on Recoverability    755

    21.5 Characterizing Schedules Based on Serializability    759

    21.6 Transaction Support in SQL    770

    21.7 Summary    772

    Review Questions    772

    Exercises    773

    Selected Bibliography    775

**Chapter 22 Concurrency Control Techniques    777**

    22.1 Two-Phase Locking Techniques for Concurrency Control    778

    22.2 Concurrency Control Based on Timestamp Ordering    788

    22.3 Multiversion Concurrency Control Techniques    791

    22.4 Validation (Optimistic) Concurrency Control Techniques    794

    22.5 Granularity of Data Items and Multiple Granularity Locking    795

    22.6 Using Locks for Concurrency Control in Indexes    798

    22.7 Other Concurrency Control Issues    800

    22.8 Summary    802

    Review Questions    803

    Exercises    804

    Selected Bibliography    804

**Chapter 23 Database Recovery Techniques    807**

    23.1 Recovery Concepts    808

    23.2 NO-UNDO/REDO Recovery Based on Deferred Update    815

    23.3 Recovery Techniques Based on Immediate Update    817

    23.4 Shadow Paging    820

    23.5 The ARIES Recovery Algorithm    821

    23.6 Recovery in Multidatabase Systems    825

    23.7 Database Backup and Recovery from Catastrophic Failures    826

    23.8 Summary    827

    Review Questions    828

    Exercises    829

    Selected Bibliography    832

**Part 10: Additional Database Topics: Security and Distribution**

**Chapter** **24 Database Security    835**

    24.1 Introduction to Database Security Issues    836

    24.2 Discretionary Access Control Based on Granting and Revoking Privileges    842

    24.3 Mandatory Access Control and Role-Based Access Control for Multilevel Security    847

    24.4 SQL Injection    855

    24.5 Introduction to Statistical Database Security    859

    24.6 Introduction to Flow Control    860

    24.7 Encryption and Public Key Infrastructures    862

    24.8 Privacy Issues and Preservation    866

    24.9 Challenges of Database Security    867

    24.10 Oracle Label-Based Security    868

    24.11 Summary    870

    Review Questions    872

    Exercises    873

    Selected Bibliography    874

**Chapter** **25 Distributed Databases    877**

    25.1 Distributed Database Concepts    878

    25.2 Types of Distributed Database Systems    883

    25.3 Distributed Database Architectures    887

    25.4 Data Fragmentation, Replication, and Allocation Techniques for Distributed Database Design    894

    25.5 Query Processing and Optimization in Distributed Databases    901

    25.6 Overview of Transaction Management in Distributed Databases    907

    25.7 Overview of Concurrency Control and Recovery in Distributed Databases    909

    25.8 Distributed Catalog Management    913

    25.9 Current Trends in Distributed Databases    914

    25.10 Distributed Databases in Oracle    915

    25.11 Summary    919

    Review Questions    921

    Exercises    922

    Selected Bibliography    924

**Part 11: Advanced Database Models, Systems, and Applications**

**Chapter** **26 Enhanced Data Models for Advanced Applications    931**

    26.1 Active Database Concepts and Triggers    933

    26.2 Temporal Database Concepts    943

    26.3 Spatial Database Concepts    957

    26.4 Multimedia Database Concepts    965

    26.5 Introduction to Deductive Databases    970

    26.6 Summary    983

    Review Questions    985

    Exercises    986

    Selected Bibliography    989

**Chapter 27 Introduction to Information Retrieval and Web Search 993**

    27.1 Information Retrieval (IR) Concepts    994

    27.2 Retrieval Models    1001

    27.3 Types of Queries in IR Systems    1007

    27.4 Text Preprocessing    1009

    27.5 Inverted Indexing    1012

    27.6 Evaluation Measures of Search Relevance    1014

    27.7 Web Search and Analysis    1018

    27.8 Trends in Information Retrieval    1028

    27.9 Summary    1030

    Review Questions    1031

    Selected Bibliography    1033

**Chapter 28 Data Mining Concepts    1035**

    28.1 Overview of Data Mining Technology    1036

    28.2 Association Rules    1039

    28.3 Classification    1051

    28.4 Clustering    1054

    28.5 Approaches to Other Data Mining Problems    1057

    28.6 Applications of Data Mining    1060

    28.7 Commercial Data Mining Tools    1060

    28.8 Summary    1063

    Review Questions    1063

    Exercises    1064

    Selected Bibliography    1065

**Chapter** **29 Overview of Data Warehousing and OLAP    1067**

    29.1 Introduction, Definitions, and Terminology    1067

    29.2 Characteristics of Data Warehouses    1069

    29.3 Data Modeling for Data Warehouses    1070

    29.4 Building a Data Warehouse    1075

    29.5 Typical Functionality of a Data Warehouse    1078

    29.6 Data Warehouse versus Views    1079

    29.7 Difficulties of Implementing Data Warehouses    1080

    29.8 Summary    1081

    Review Questions    1081

    Selected Bibliography    1082

**Appendix A Alternative Diagrammatic Notations for ER Models 1083**

**Appendix B Parameters of Disks 1087**

**Appendix** **C Overview of the QBE Language 1091**

    C.1 Basic Retrievals in QBE 1091

    C.2 Grouping, Aggregation, and Database Modification in QBE 1095

**Appendix** **D Overview of the Hierarchical Data Model**(located on the Companion Website at <http://www.aw.com/elmasri>)

**Appendix** **E Overview of the Network Data Model**(located on the Companion Website at <http://www.aw.com/elmasri>)

**Selected Bibliography 1099**

**Index 1133**