

Contents

Preface 7
About the Authors 30
m part 1
Introduction to Databases
chapter 1 Databases and Database Users 33 1.1 Introduction 34 1.2 An Example 36 1.3 Characteristics of the Database Approach 40 1.4 Actors on the Scene 45 1.5 Workers behind the Scene 47 1.6 Advantages of Using the DBMS Approach 47 1.7 A Brief History of Database Applications 53 1.8 When Not to Use a DBMS 57 1.9 Summary 57 Review Questions 58 Exerc see 58 Selected Bibliography 59
chapter 2 Database System Concepts and Architecture 61 2.1 Data Models, Schemas, and Instances 62 2.2 Three-Schema Architecture and Data Independence 66
2.3 Database Languages and Interfaces 68 2.4 The Database System Environment 72 2.5 Centralized and Client/Server Architectures for DBMSs 76 2.6 Classification of Database Management Systems 81 2.7 Summary 84 Review Questions 85 Exercises 85
Selected Bibliography 86

part 2

Conceptual Data Modeling and Database Design III

Data Modeling Using the Entity-Relationship (ER) Model 89

3.1	Using High-Level Cond	eptual Data Models
	for Database Design	90

- 3.2 A Sample Database Application 92
- 3.3 Entity Types, Entity Sets, Attributes, and Keys 93
- 3.4 Relationship Types, Relationship Sets, Roles, and Structural Constraints
- 3.5 Weak Entity Types 109
- 3.6 Refining the ER Design for the COMPANY Database
- 3.7 ER Diagrams, Naming Conventions, and Design Issues
- 3.8 Example of Other Notation: UML Class Diagrams 115
- 3.9 Relationship Types of Degree Higher than Two 118
- 3.10 Another Example: A UNIVERSITY Database 122
- 3.11 Summary 124

Review Questions

Exercises 126

Laboratory Exercises 133

Selected Bibliography

chapter 4 The Enhanced Entity-Relationship (EER) Model

- 4.1 Subclasses, Superclasses, and Inheritance 138
- 4.2 Specialization and Generalization
- 4.3 Constraints and Characteristics of Spec alization and Generalization Hierarchies:
- 4.4 Modeling of UNION Types Using Categories
- 4.5 A Sample UNIVERSITY EER Schema, Design Choices, and Formal Definitions 152
- 4.6 Example of Other Notation: Representing Specialization and Generalization in UML Class Diagrams
- 4.7 Data Abstraction, Knowledge Representation, and Ontology Concepts 158
- 4.8 Summary 165

Review Questions

Exercises 166

Laboratory Exercises

part 3

The Relational Data Model and SQL III

chapter 5 The Relational Data Model and Relational Database Constraints 179

5.1 Relational Model Concepts 180

5.2 Relational Model Constraints and Relational Database Schemas 187

5.3 Update Operations, Transactions, and Dealing with Constraint Violations 195

5.4 Summary 199

Review Questions 200

Exercises 200

Selected Bibliography 205

chapter 6 Basic SQL 207

6.1 SQL Data Definition and Data Types 209

6.2 Specifying Constraints in SQL 214

6.3 Basic Retrieval Queries in SQL 217

6.4 INSERT, DELETE, and UPDATE Statements in SQL 228

6.5 Additional Features of SQL 231

6.6 Summary 232

Review Questions 233

Exercises 233

Selected Bibliography 235

chapter 7 More SQL: Complex Queries, Triggers, Views, and Schema Modification 237

7.1 More Complex SQL Retrieval Queries 237

7.2 Specifying Constraints as Assertions and Actions as Triggers 255

7.3 Views (Virtual Tables) in SQL 258

7.4 Schema Change Statements in SQL 262

7.5 Summary 264

Review Questions 266

Exercises 266

Selected Bibliography 268

chapter 8 The Relational Algebra and Relational Calculus 269

8.1 Unary Relational Operations: SELECT and PROJECT 271

8.2 Relational Algebra Operations from Set Theory 276

8.3 Binary Relational Operations: JO 8.4 Additional Relational Operations	289	SION	281
8.5 Examples of Queries in Relationa	Algebra	295	
8.6 The Tuple Relational Calculus	298	0.00	
8.7 The Domain Relational Calculus 8.8 Summary 309	307		
Review Questions 310 Exercises 311			
Laboratory Exercises 316			
Selected Bibliography 318			

chapter 9 Relational Database Design by ER- and EER-to-Relational Mapping

9.1 Relational Database Design Using ER-to Relational Mapping 9.2 Mapping EER Model Constructs to Relations 333 9.3 Summary Review Questions 333 Exercises Laboratory Exercises 335 336 Selected Bibliography

m part 4

Database Programming Techniques

chapter 10 Introduction to SQL Programming 339 Techniques

10.1 Overview of Database Programming Techniques and Issues 340 10.2 Embedded SQL Dynamic SQL, and SQLJ 10.3 Database Programming with Function Calls and Class Libraries: SQL/CLI and JDBC 356 10.4 Database Stored Procedures and SQL/PSM 10.5 Comparing the Three Approaches 368 369 10.6 Summary Review Questions 370 Exercises Selected Bibliography 371

Web Database Programming Using PHP chapter 11

11.1 A Simple PHP Example

11.2 Overview of Basic Features of PHP 376

11.3 Overview of PHP Database Programming 383
11.4 Brief Overview of Java Technologies for Database Web
Programming 388
11.5 Summary 388
Review Questions 399
Exercises 389

part 5

Selected Bibliography 389

Object, Object-Relational, and XML: Concepts, Models, Languages, and Standards M

chapter 12 Object and Object-Relational Databases 393

12.1 Overview of Object Database Concepts 395

12.2 Object Database Extensions to SΩL 409

12.3 The ODMG Object Model and the Object Definition Language ODL 416

12.4 Object Database Conceptual Design 435

12.5 The Object Query Language OQL 438

12.6 Overview of the C++ Language Binding in the ODMG Standard 447

12.7 Summary 448

Review Questions 450

Exercises 451

Selected Bibliography 452

chapter 13 XML: Extensible Markup Language 455

13.1 Structured, Semistructured, and Unstructured Data 456

13.2 XML Hierarchical (Tree) Data Model 460

13.3 XML Documents, DTD, and XML Schema 463

13.4 Storing and Extracting XML Documents from Databases 472

13.5 XML Languages 473

13.6 Extracting XML Documents from Relational Databases 477

13.7 XML/SQL: SQL Functions for Creating XML Data 483

13.8 Summary 485

Review Questions 486

Exercises 486

m part 6

Database Design Theory and Normalization

chapter 14 Basics of Functional Dependencies and Normalization for Relational Databases 489

- 14.1 Informal Design Guidelines for Relation Schemas 491
- 14.2 Functional Dependencies 501
- 14.3 Normal Forms Based on Primary Keys 504
- 14.4 General Definitions of Second and Third Normal Forms 513
- 14.5 Boyce-Codd Normal Form 517
- 14.6 Multivalued Dependency and Fourth Normal Form 521
- 14.7 Join Dependencies and Fifth Normal Form 524
- 14.8 Summary 525

Review Questions 526

Exercises 527

Laboratory Exercises 531

Selected Bibliography 532

chapter 15 Relational Database Design Algorithms and Further Dependencies 533

- 15.1 Further Topics in Functional Dependencies: Inference Rules, Ecuiva ence, and Minimal Cover 535
- 15.2 Properties of Relational Decompositions 543
- 15.3 Algorithms for Relational Database Schema Design 549
- 15.4 About Nulls, Dangling Tuples, and Alternative Relational Designs 553
- 15.5 Further Discussion of Multivalued Dependencies and 4NF 557
- 15.6 Other Dependencies and Normal Forms 560
- 15.7 Summary 563

Review Questions 564

Exercisos 565

Laboratory Exercises 566

part 7

File Structures, Hashing, Indexing, and Physical Database Design ₩

chapter 16 Disk Storage, Basic File Structures, Hashing, and Modern Storage Architectures 571

10 May 17 hours	TORRORS AND ADMINISTRATION OF THE PARTY OF T	
161	Introduction	572
10.1	IFTE CALGERIAN	1312

- 16.2 Secondary Storage Devices 577
- 16.3 Buffering of Blocks
- 16.4 Placing File Records on Disk 590
- 16.5 Operations on Files 594
- 16.6 Files of Unordered Records (Heap Files)
- 16.7 Files of Ordered Records (Sorted Files) 598

597

- 16.8 Hashing Techniques 602
- 16.9 Other Primary File Organizations 612
- 16.10 Parallelizing Disk Access Using RAID Technology 614
- 16.11 Modern Storage Architectures 618
- 16.12 Summary 622
- Review Questions 623

Exercises 625

Selected Bibliography 628

chapter 17 Indexing Structures for Files and Physical Database Design 631

- 17.1 Types of Single-Level Ordered Indexes 632
- 17.2 Multilevel Indexes 643
- 17.3 Dynamic Multilevel Indexes Using B-Trees and B⁺-Trees 647
- 17.4 Indexes on Multiple Keys 661
- 17.5 Other Types of Indexes 663
- 17.6 Some General Issues Concerning Indexing 668
- 17.7 Physical Database Design in Relational Databases 673
- 17.8 Summary 676
- Review Questions 677
- Exercises 678
- Selected Bibliography 680

m part 8

Query Processing and Optimization

10.1	Translating SQL Queries into Relational Al and Other Operators 687	gebra
18.2	Algorithms for External Sorting 690	
18.3	Algorithms for SELECT Operation 693	
18.4	Implementing the JOIN Operation 698	
18.5	Algorithms for PROJECT and Set Operation	ons 7
18.6	Implementing Aggregate Operations and E Types of JOINs 708	Different
18.7	Combining Operations Using Pipelining	711
18.8	Parallel Algorithms for Query Processing	713
18.9	Summary 718	
Revie	ew Questions 718	
Ever	cises 719	
PAGIC		

685

chapter 19 Query Optimization 721

n	apte	duery Optimization 72	1
	19.1	Query Trees and Heuristics for Query	
		Optimization 722	
	19.2	Choice of Query Execution Plans 731	
	19.3	Use of Selectivities in Cost-Based	
		Optimization 740	
	19.4	Cost Functions for SELECT Operation	744
	19.5	Cost Functions for the JOIN Operation	747
	19.6	Example to Illustrate Cost-Based Query	
		Optimization 756	
	19.7	Additional Issues Related to Query	
		Optimization 758	
	19.8	An Example of Query Optimization in Data	
		Warehouses 761	
	19.9	Overview of Query Optimization in Oracle	763
	19.10	Semantic Query Optimization 767	
	19.1	1 Summary 768	
	Revie	w Questions 769	
	Exerc	oises 770	
	Selec	cted Bibliography 770	



Transaction Processing, Concurrency Control, and Recovery ■

chapter 20 Introduction to Transaction Processing Concepts and Theory 775

					general contracts
20.1	Introduct on	to	Transaction	Processing	776
Eliza I	HILLOGIGGEOR	100	11000000000	1 10000001 19	

- 20.2 Transaction and System Concepts 783
- 20.3 Desirable Properties of Transactions 787
- 20.4 Characterizing Schedules Based on Recoverability 789
- 20.5 Characterizing Schedules Based on Serializability 793
- 20.6 Transaction Support in SQL 803
- 20.7 Summary 806
- Review Questions 807
- Exercises 807
- Selected Bibliography 809

chapter 21 Concurrency Control Techniques 811

- 21.1 Two-Phase Locking Techniques for Concurrency Control 812
- 21.2 Concurrency Control Based on Timestamp Ordering 822
- 21.3 Multiversion Concurrency Control Techniques 825
- 21.4 Validation (Optimistic) Techniques and Snapshot Isolation Concurrency Control 828
- 21.5 Granularity of Data Items and Multiple Granularity
 Locking 830
- 21.6 Using Locks for Concurrency Control in Indexes 835
- 21.7 Other Concurrency Control Issues 836
- 21.8 Summary 837
- Review Questions 838
- Exercises 839
- Selected 3ibliography 840

chapter 22 Database Recovery Techniques 843

- 22.1 Recovery Concepts 844
- 22.2 NO-UNDO/REDO Recovery Based on Deferred
 Update 851
- 22.3 Recovery Techniques Based on Immediate Update 853

22.4 Shadow Paging 856 22.5 The ARIES Recovery Algorithm 857 22.6 Recovery in Multidatabase Systems 861 22.7 Database Backup and Recovery from Catastrophic Failures 863 22.8 Summary 863 Review Questions 864 Exercises 865 Selected Bibliography 868	2
m part 10	
Distributed Databases, NOSQL Systems,	
and Big Data M	
1100	
chapter 23 Distributed Database Concepts 871	
23.1 Distributed Database Concepts 872	
23.2 Data Fragmentation, Replication, and Allocation Techniques for Eistributed Database Design 877	
23.3 Overview of Concurrency Control and Recovery in Distributed Databases 884	
23.4 Overview of Transaction Management in Distributed Databases	88 89
Review Questions 907	
Exercises 908	
Selected Bibliography 910	
24	
chapter 24 NOSQL Databases and Big Data Storage Systems 913	
24.1 Introduction to NOSOL Systems 914 24.2 The CAP Theorem 918	
24.3 Document-Based NOSQL Systems and MongoDB 920 24.4 NOSQL Key-Value Stores 925	
24.5 Column-Based or Wide Column NOSQL Systems 930 24.6 NOSQL Graph Databases and Neo4j 933 24.7 Summary 939 Review Questions 939	
Selected Bibliography 940	

chapter 25	Big Data Tech	nologies	Based	on	MapReduce
	and Hadoop	941			

25.1 What Is Big Data? 944

25.2 Introduction to MapReduce and Hadoop 946

25.3 Hadoop Distributed File System (HDFS) 951

25.4 MapReduce: Additional Details 956

25.5 Hadoop v2 alas YARN 96

25.6 General Discussion 974

25.7 Summary 983

Review Questions 984

Selected Bibliography 986

s part 11

Advanced Database Models, Systems, and Applications III

chapter 26 Enhanced Data Models: Introduction to Active, Temporal, Spatial, Multimedia, and Deductive Databases 991

26.1 Active Database Concepts and Triggers 993

26.2 Temporal Database Concepts 1004

26.3 Spatial Database Concepts 1017

26.4 Multimedia Database Concepts 1024

26.5 Introduction to Deductive Databases 1029

26.6 Summary 1042

Review Questions - 1044

Exercises 1045

Selected Bibliography 1048

chapter 27 Introduction to Information Retrieval and Web Search 1051

27.1 Information Retrieval (IR) Concepts 1052

27.2 Retrieval Models 1059

27.3 Types of Queries in IR Systems 1065

27.4 Text Preprocessing 1067

27.5 Inverted Indexing 1070

27.6 Evaluation Measures of Search Relevance 1074

27.7 Web Search and Analysis 1077

1087 27.8 Trends in Information Retrieval 27.9 Summary 1093 Review Questions 1094 Selected Bibliography 1096

chapter 28 Data Mining Concepts 1099

28.1 Overview of Data Mining Technology 1100

28.2 Association Rules

28.3 Classification 1118

28.4 Clustering

28.5 Approaches to Other Data Mining Problems

28.6 Applications of Data Mining

28.7 Commercial Data Mining Tools 1124

28.8 Summary 1127

Review Questions

1128 Exercises

Selected Bioliography 1129

chapter 29 Overview of Data Warehousing and OLAP 1131

29.1 Introduction, Definitions, and Terminology

29.2 Characteristics of Data Warehouses 1133

29.3 Data Modeling for Data Warehouses 29.4 Building a Data Warehouse 1141

29.5 Typical Functionality of a Data Warehouse

29.6 Data Warehouse versus Views 1145

29.7 Difficulties of Implementing Data Warehouses

29.8 Summary

Review Questions

Selected Bibliography 1148

part 12

Additional Database Topics: Security M

chapter 30 Database Security 1151

30.1 Introduction to Database Security Issues 1152

30.2 Discretionary Access Control Based on Granting and Revoking Privileges 1159

30.3 Mandatory Access Control and Role-Based Access Control for Multilevel Security 1164

30.4 SQL Injection 1173 30.5 Introduction to Statistical Database Security 1176 30.6 Introduction to Flow Control 30.7 Encryption and Public Key Infrastructures 1179 30.8 Privacy Issues and Preservation 30.9 Challenges to Maintaining Database Security 30.10 Oracle Label-Based Security 30.11 Summary 1188 Review Questions 1189

appendix A Alternative Diagrammatic Notations for ER Models

appendix B Parameters of Disks

appendix C Overview of the QBE Language 1201

C.1 Basic Retrievals in QBE 1201

C.2 Grouping, Aggregation, and Database Modification in QBE 1205

Overview of the Hierarchical Data Model (located on the Companion Website at www.pearsonglobaleditions.com/Elmasril

Overview of the Network Data Model (located on the Companion Website at www.pearscnglobaleditions.com/Elmasri)

Bibliography 1209

Index 1245

Exercises