



## CONTENTS

### Preface 1



### PART 1 PROBLEM SOLVING AND ALGORITHMS

#### 1 Introduction to Computer Science 9

- Introduction 9
- 1.1 Computer Science 10
- 1.2 Computer Science across the Disciplines 20
- 1.3 Computer Science and the Future of Society 25
- Chapter Review 33

#### 2

#### Computational Thinking and Design Reusability 39

- Introduction 39
- 2.1 Computational Thinking 40
- 2.2 Architecting Solutions with Adaptive Design Reuse in Mind 53
- 2.3 Evolving Architectures into Useable Products 73
- Chapter Review 83

#### 3

#### Data Structures and Algorithms 91

- Introduction 91
- 3.1 Introduction to Data Structures and Algorithms 91
- 3.2 Algorithm Design and Discovery 100
- 3.3 Formal Properties of Algorithms 107
- 3.4 Algorithmic Paradigms 113
- 3.5 Sample Algorithms by Problem 119
- 3.6 Computer Science Theory 127
- Chapter Review 131



### PART 2 REALIZATIONS OF ALGORITHMS

#### 4

#### Linguistic Realization of Algorithms: Low-Level Programming Languages 145

- Introduction 145
- 4.1 Models of Computation 146
- 4.2 Building C Programs 158
- 4.3 Parallel Programming Models 175
- 4.4 Applications of Programming Models 181
- Chapter Review 184

#### 5

#### Hardware Realizations of Algorithms: Computer Systems Design 195

- Introduction 195

<b>5.1</b>	Computer Systems Organization	196
<b>5.2</b>	Computer Levels of Abstraction	200
<b>5.3</b>	Machine-Level Information Representation	208
<b>5.4</b>	Machine-Level Program Representation	214
<b>5.5</b>	Memory Hierarchy	221
<b>5.6</b>	Processor Architectures	230
	Chapter Review	234

## **6 Infrastructure Abstraction Layer: Operating Systems 243**

	Introduction	243
<b>6.1</b>	What Is an Operating System?	244
<b>6.2</b>	Fundamental OS Concepts	250
<b>6.3</b>	Processes and Concurrency	262
<b>6.4</b>	Memory Management	272
<b>6.5</b>	File Systems	279
<b>6.6</b>	Reliability and Security	284
	Chapter Review	290

## PART 3 DESIGNING AND DEVELOPING SOFTWARE SOLUTIONS

### **7 High-Level Programming Languages 303**

	Introduction	303
<b>7.1</b>	Programming Language Foundations	304
<b>7.2</b>	Programming Language Constructs	317
<b>7.3</b>	Alternative Programming Models	337
<b>7.4</b>	Programming Language Implementation	346
	Chapter Review	353

### **8 Data Management 365**

	Introduction	365
<b>8.1</b>	Data Management Focus	366
<b>8.2</b>	Data Management Systems	372
<b>8.3</b>	Relational Database Management Systems	378
<b>8.4</b>	Nonrelational Database Management Systems	396
<b>8.5</b>	Data Warehousing, Data Lakes, and Business Intelligence	403
<b>8.6</b>	Data Management for Shallow and Deep Learning Applications	408
<b>8.7</b>	Informatics and Data Management	418
	Chapter Review	420

### **9 Software Engineering 435**

	Introduction	435
<b>9.1</b>	Software Engineering Fundamentals	436
<b>9.2</b>	Software Engineering Process	446

**9.3 Special Topics** 474  
Chapter Review 496

## **10 Enterprise and Solution Architectures Management 507**

Introduction 507  
**10.1 Patterns Management** 508  
**10.2 Enterprise Architecture Management Frameworks** 516  
**10.3 Solution Architecture Management** 551  
Chapter Review 556

# PART 4 BUILDING MODERN END-TO-END SOLUTIONS TO BUSINESS AND SOCIAL PROBLEMS

## **11 Web Applications Development 565**

Introduction 565  
**11.1 Modern Web Applications Architectures** 566  
**11.2 Sample Responsive WAD with Bootstrap and Django** 584  
**11.3 Sample Responsive WAD with Bootstrap/React and Node** 610  
**11.4 Sample Responsive WAD with Bootstrap/React and Django** 625  
**11.5 Sample Native WAD with React Native and Node or Django** 630  
**11.6 Sample Ethereum Blockchain Web 2.0/Web 3.0 Application** 643  
Chapter Review 656

## **12 Cloud-Native Applications Development 665**

Introduction 665  
**12.1 Introduction to Cloud-Native Applications** 666  
**12.2 Cloud-Based and Cloud-Native Applications Deployment Technologies** 690  
**12.3 Example PaaS and FaaS Deployments of Cloud-Native Applications** 711  
Chapter Review 750

## **13 Hybrid Multicloud Digital Solutions Development 761**

Introduction 761  
**13.1 Hybrid Multicloud Solutions and Cloud Mashups** 762  
**13.2 Big Cloud IaaS Mainstream Capabilities** 766  
**13.3 Big Cloud PaaS Mainstream Capabilities** 774  
**13.4 Towards Intelligent Autonomous Networked Super Systems** 790  
Chapter Review 805

# PART 5 HUMAN-CENTERED RESPONSIBLE COMPUTING

## **14 Cyber Resources Qualities and Cyber Computing Governance 817**

Introduction 817  
**14.1 Cyber Resources Management Frameworks** 818  
**14.2 Cybersecurity Deep Dive** 839