## **Table of Contents**

1.		
	1.2 Data Types	
	1.3 Data Structures	
	1.4 Abstract Data Types (ADTs)	16
	1.5 What is an Algorithm?	16
	1.6 Why the Analysis of Algorithms?	16
	1.7 Goal of the Analysis of Algorithms	17
	1.8 What is Running Time Analysis?	17
	1.9 How to Compare Algorithms	
	1.10 What is Rate of Growth?	17
	1.11 Commonly Used Rates of Growth-	17
	1.12 Types of Analysis	18
	1.13 Asymptotic Notation	19
	1.14 Big-O Notation	19
	1.15 Omega-Ω Notation [Lower Bounding Function]————————————————————————————————————	20
	1.16 Theta-Θ Notation	20
	1.17 Why is it called Asymptotic Analysis?	21
	1.18 Guidelines for Asymptotic Analysis	21
	1.20 Simplifying properties of asymptotic notations————————————————————————————————————	22
	1.21 Commonly used Logarithms and Summations	23
	1.22 Master Theorem for Divide and Conquer Recurrences	23
	1.23 Divide and Conquer Master Theorem: Problems & Solutions	23
	1.24 Master Theorem for Subtract and Conquer Recurrences	24
	1.25 Variant of Subtraction and Conquer Master Theorem	24
	1.26 Method of Guessing and Confirming	25
	1.27 Amortized Analysis	26
	1.28 Algorithms Analysis: Problems & Solutions	26
2.	Recursion and Backtracking	36
	2.1 Introduction	36
	2.2 What is Recursion?	36
	2.3 Why Recursion?	36
	2.4 Format of a Recursive Function-	36
	2.5 Recursion and Memory (Visualization)	37
	2.6 Recursion versus Iteration	
	2.7 Notes on Recursion	37
	2.8 Example Algorithms of Recursion	38
	2.9 Recursion: Problems & Solutions	
	2.10 What is Backtracking?	38
	2.11 Example Algorithms of Backtracking	39
	2.12 Backtracking: Problems & Solutions	39

3.	Linked Lists	41
	3.1 What is a Linked List?	41
	3.2 Linked Lists ADT	41
	3.3 Why Linked Lists?	41
	3.4 Arrays Overview	41
	3.5 Comparison of Linked Lists with Arrays and Dynamic Arrays	42
	3.6 Singly Linked Lists	43
	3.7 Doubly Linked Lists	48
	3.8 Circular Linked Lists	52
	3.9 A Memory-efficient Doubly Linked List	56
	3.10 Unrolled Linked Lists	57
	3.11 Skip Lists	61
	3.12 Linked Lists: Problems & Solutions	64
4.	Stacks	85
	4.1 What is a Stack?	
	4.2 How Stacks are used	
	4.3 Stack ADT	
	4.4 Applications	
	4.5 Implementation	86
	4.6 Comparison of Implementations	
	4.7 Stacks: Problems & Solutions	92
5.	Queues	
0.	5.1 What is a Queue?	
	5.2 How are Queues Used?	
	5.3 Queue ADT	
	5.4 Exceptions	
	5.5 Applications	
	5.6 Implementation	
	5.7 Queues: Problems & Solutions	
6.	Trees	
	6.1 What is a Tree?	
	6.2 Glossary	
	6.3 Binary Trees	
	6.4 Types of Binary Trees	
	6.5 Properties of Binary Trees	
	6.6 Binary Tree Traversals———————————————————————————————————	
	6.7 Generic Trees (N-ary Trees)	The state of the s
	6.8 Threaded Binary Tree Traversals (Stack or Queue-less Traversals)	
	6.9 Expression Trees	
	6.10 XOR Trees	
	6.11 Binary Search Trees (BSTs)	
	6.12 Balanced Binary Search Trees	
	6.13 AVL (Adelson-Velskii and Landis) Trees	

	6.14 Other Variations on Trees	189
	6.15 Supplementary Questions————————————————————————————————————	
7.	. Priority Queues and Heaps	
	7.1 What is a Priority Queue?	
	7.2 Priority Queue ADT	
	7.3 Priority Queue Applications	
	7.4 Priority Queue Implementations	
	7.5 Heaps and Binary Heaps	
	7.6 Binary Heaps	
	7.7 Heapsort	
	7.8 Priority Queues [Heaps]: Problems & Solutions	
8.		
	8.1 Introduction	
	8.2 Equivalence Relations and Equivalence Classes——————————————————————————————————	
	8.3 Disjoint Sets ADT	
	8.4 Applications	202
	8.5 Tradeoffs in Implementing Disjoint Sets ADT	
	8.8 Fast UNION Implementation (Slow FIND)	
	8.9 Fast UNION Implementations (Quick FIND)	905
	8.10 Summary	907
	8.11 Disjoint Sets: Problems & Solutions	
9.		900
	9.1 Introduction	209
	9.2 Glossary	209
	0.9 Applications of C	
	9.4 Graph Representation	
	9.5 Graph Traversals	
	9.6 Topological Sort	
	9.7 Shortest Path Algorithms	997
	9.8 Minimal Spanning Tree	
	9.9 Graph Algorithms: Problems & Solutions	935
10.	. Sorting	
	10.1 What is Sorting?	
	10.2 Why is Sorting Necessary?	
	10.3 Classification of Sorting Algorithms	
	10.4 Other Classifications	
	10.5 Bubble Sort	
	10.6 Selection Sort	
	10.7 Insertion Sort	
	10.8 Shell Sort	254
	10.9 Merge Sort	
	10.10 Heap Sort	
	10.11 Quick Sort	
		203

10.12 Tree Sort	263
10.13 Comparison of Sorting Algorithms	263
10.14 Linear Sorting Algorithms	264
10.15 Counting Sort	264
10.16 Bucket Sort (or Bin Sort)	264
10.17 Radix Sort	265
10.18 Topological Sort	265
10.19 External Sorting	265
10.20 Sorting: Problems & Solutions	266
11. Searching	
11.1 What is Searching?	
11.2 Why do we need Searching?	
11.3 Types of Searching	
11.4 Unordered Linear Search-	
11.5 Sorted/Ordered Linear Search	277
11.6 Binary Search	
11.7 Interpolation Search	
11.8 Comparing Basic Searching Algorithms-	
11.9 Symbol Tables and Hashing	
11.10 String Searching Algorithms	
11.11 Searching: Problems & Solutions	
12. Selection Algorithms [Medians]	
12.1 What are Selection Algorithms?	
12.2 Selection by Sorting	
12.3 Partition-based Selection Algorithm	
12.4 Linear Selection Algorithm - Median of Medians Algorithm	
12.5 Finding the K Smallest Elements in Sorted Order	
12.6 Selection Algorithms: Problems & Solutions	
13. Symbol Tables	
13.1 Introduction	
13.2 What are Symbol Tables?	
13.3 Symbol Table Implementations	
13.4 Comparison Table of Symbols for Implementations	
14. Hashing	
14.1 What is Hashing?	
14.2 Why Hashing?	
14.3 Hash Table ADT	
14.4 Understanding Hashing	
14.5 Components of Hashing-	
14.6 Hash Table	
14.7 Hash Function-	
14.8 Load Factor	
14.9 Collisions	
	311

14.10 Collision Resolution Techniques	311
14.11 Separate Chaining	311
14.12 Open Addressing	312
14.13 Comparison of Collision Resolution Techniques	313
14.14 How Hashing Gets O(1) Complexity	313
14.15 Hashing Techniques	313
14.16 Problems for which Hash Tables are not suitable	314
14.17 Bloom Filters	314
14.18 Hashing: Problems & Solutions	315
15. String Algorithms	325
15.1 Introduction	325
15.2 String Matching Algorithms	325
15.3 Brute Force Method	325
15.4 Rabin-Karp String Matching Algorithm	326
15.5 String Matching with Finite Automata	326
15.6 KMP Algorithm	
15.7 Boyer-Moore Algorithm	330
15.8 Data Structures for Storing Strings	330
15.9 Hash Tables for Strings-	330
15.10 Binary Search Trees for Strings	
15.11 Tries	330
15.12 Ternary Search Trees	332
15.13 Comparing BSTs, Tries and TSTs	335
15.14 Suffix Trees	335
15.15 String Algorithms: Problems & Solutions	337
16. Algorithms Design Techniques	345
16.1 Introduction	
16.2 Classification	345
16.3 Classification by Implementation Method	345
16.4 Classification by Design Method	346
16.5 Other Classifications	346
17. Greedy Algorithms	348
17.1 Introduction	348
17.2 Greedy Strategy	348
17.3 Elements of Greedy Algorithms	348
17.4 Does Greedy Always Work?	
17.5 Advantages and Disadvantages of Greedy Method	348
17.6 Greedy Applications	348
17.7 Understanding Greedy Technique	
17.8 Greedy Algorithms: Problems & Solutions	351
18. Divide and Conquer Algorithms	356
18.1 Introduction	356
18.2 What is the Divide and Conquer Strategy?	356

18.3 Does Divide and Conquer Always Work?	356
18.4 Divide and Conquer Visualization	356
18.5 Understanding Divide and Conquer	357
18.6 Advantages of Divide and Conquer	357
18.7 Disadvantages of Divide and Conquer	357
18.8 Master Theorem	357
18.9 Divide and Conquer Applications	358
18.10 Divide and Conquer: Problems & Solutions	358
19. Dynamic Programming	369
19.1 Introduction	369
19.2 What is Dynamic Programming Strategy?	369
19.3 Properties of Dynamic Programming Strategy	369
19.4 Greedy vs Divide and Conquer vs DP	369
19.5 Can DP solve all problems?	370
19.6 Dynamic Programming Approaches	370
19.7 Understanding DP Approaches	370
19.8 Examples of DP Algorithms	373
19.9 Longest Common Subsequence	373
19.10 Dynamic Programming: Problems & Solutions	375
20. Complexity Classes	400
20.1 Introduction	400
20.2 Polynomial/Exponential Time	400
20.3 What is a Decision Problem?	400
20.4 Decision Procedure	400
20.5 What is a Complexity Class?	400
20.6 Types of Complexity Classes	401
20.7 Reductions	402
20.8 Complexity Classes: Problems & Solutions	404
21. Miscellaneous Concepts	406
21.1 Introduction	406
21.2 Hacks on Bit-wise Programming	406
21.3 Other Programming Questions	409
References	416