

**Chapter 1 : Introduction to Formal Languages****1-1 to 1-5**

1.1	Introduction to Formal Language.....	1-1
1.2	Alphabets and Languages.....	1-1
1.2.1	Kleene Closure.....	1-2
1.2.2	Recursive Definition of a Language.....	1-3
1.3	Finite Representation of Language.....	1-3
1.4	Introduction to Language Translation Logic.....	1-4
1.5	Essential of Translation.....	1-4
1.6	University Questions and Answers.....	1-5

Chapter 2 : Finite Automata**2-1 to 2-77**

2.1	Introduction to Finite Automata.....	2-1
2.1.1	Working of a Finite Automata.....	2-1
2.1.2	Some Important Terms.....	2-3
2.1.2(A)	Alphabet.....	2-3
2.1.2(B)	Strings (words).....	2-3
2.1.2(C)	Languages.....	2-3
2.1.2(D)	Symbol.....	2-4
2.1.3	Applications of Finite Automata.....	2-4
2.2	Deterministic Finite Automata (DFA).....	2-4
2.2.1	Definition of a DFA.....	2-4
2.2.2	Representation of a DFA.....	2-4

2.2.3	Designing a DFA.....	2-5
2.2.4	Solved Examples on DFA.....	2-8
2.2.4(A)	Examples on Counting of Symbols.....	2-8
2.2.4(B)	Examples on Substring.....	2-13
2.2.4(C)	Examples of Divisibility.....	2-20
2.2.5	Language of DFA.....	2-22
2.3	Equivalence of DFAs.....	2-23
2.4	Closure Property of Language Accepted by a DFA.....	2-25
2.4.1	Union, Intersection, Difference.....	2-25
2.4.2	Complementation.....	2-28
2.5	Minimization of DFA.....	2-28
2.5.1	Algorithm for Minimization DFA's.....	2-28
2.6	Non-deterministic Finite Automata.....	2-32
2.6.1	Definition of NFA.....	2-32
2.6.2	Processing of a String by NFA.....	2-32
2.6.3	NFA to DFA Conversion.....	2-36
2.6.4	NFA with ϵ -Transitions.....	2-50
2.6.4(A)	Equivalence of ϵ -NFA and NFA.....	2-50
2.6.4(B)	The Formal Notation for an ϵ -NFA.....	2-52
2.6.4(C)	ϵ -Closures.....	2-52
2.6.4(D)	ϵ -NFA to DFA.....	2-53



2.6.5	Difference between NFA and DFA.....	2-58	3.3	Determination of Regular Expression.....	3-7
2.7	Finite Automata as Output Devices	2-59	3.3.1	Language Generated by a Regular Expression	3-7
2.7.1	A Sample Mealy Machine	2-59	3.3.2	Basic Properties of Regular Expressions.....	3-7
2.7.2	Formal Definition of a Mealy Machine	2-60	3.4	DFA to Regular Expression.....	3-16
2.7.3	A Sample Moore Machine	2-60	3.4.1	State/Loop Elimination Process	3-16
2.7.4	Formal Definition of a Moore Machine	2-60	3.4.1(A)	A Generic One State Machine	3-16
2.7.5	Conversion of a Mealy Machine into a Moore Machine.....	2-65	3.4.1(B)	A Generic Two State Machine.....	3-16
2.8	Minimization of a Mealy Machine.....	2-70	3.4.2	Arden's Theorem.....	3-25
2.8.1	Conversion of a Moore Machine into a Mealy Machine.....	2-72	3.4.2(A)	Application of Arden's Theorem.....	3-26
2.8.2	Difference between Moore and Mealy Machine.....	2-74	3.5	FA Limitations.....	3-29
2.9	FSM for Vending Machine	2-75	3.6	Pumping Lemma for Regular Languages.....	3-29
2.10	FSM for Spell Checker.....	2-75	3.6.1	Definition of Pumping Lemma.....	3-30
2.11	University Questions and Answers.....	2-75	3.6.2	Interpretation of Pumping Lemma.....	3-30
<hr/>			3.6.3	Proof of Pumping Lemma.....	3-30
Chapter 3 : Regular Expressions (RE) 3-1 to 3-39			3.6.4	Applications of Pumping Lemma.....	3-31
3.1	Introduction	3-1	3.7	Closure Properties of Regular Language	3-34
3.1.1	Precedence of Operators	3-3	3.7.1	Regular Language is Closed under Union.....	3-34
3.2	Finite Automata Representing a Regular Expression	3-3	3.7.2	Regular Language is Closed under Concatenation.....	3-34
3.2.1	Composite Finite State Automata	3-3	3.7.3	Regular Language is Closed under Kleene Star	3-35
3.2.2	Algebraic Laws for Regular Expressions	3-6	3.7.4	Regular Language is Closed under Complementation.....	3-35



3.7.5	Regular Language is Closed under Intersection 3-35	4.3	Ambiguous Grammar 4-19
3.7.6	Regular Languages are Closed under Difference 3-35	4.4	Simplification of CFG 4-25
3.7.7	Regular Languages are Closed under Reversal 3-36	4.4.1	Elimination of Useless Symbols 4-26
3.8	Decision Properties of Regular Language 3-37	4.4.1(A)	Non-generating Symbols 4-26
3.9	Applications of R.E. 3-37	4.4.1(B)	Non-reachable Symbols 4-27
3.9.1	R.E. in Unix 3-37	4.4.2	Elimination of ϵ -productions 4-29
3.9.2	Lexical Analysis 3-38	4.4.3	Elimination of Unit Productions 4-31
3.10	Myhill - Nerode Theorem 3-38	4.5	Normal Forms for CFG 4-35
3.11	University Questions and Answers 3-38	4.5.1	Chomsky Normal Form (CNF) 4-35
<hr/>		4.5.1(A)	Algorithm for CFG to CNF Conversion 4-35
Chapter 4 : Context Free Grammars (CFG) and Languages 4-1 to 4-66		4.5.2	Greibach Normal Form (GNF) 4-40
4.1	An Example to Explain Grammar 4-1	4.5.2(A)	Removing Left Recursion 4-40
4.2	Context Free Grammar 4-3	4.5.2(B)	Algorithm for Conversion from CFG to GNF 4-41
4.2.1	Notations 4-3	4.6	Chomsky Classification for Grammar 4-46
4.2.2	The Language of a Grammar 4-3	4.6.1	Type 3 or Regular Grammar 4-46
4.2.2(A)	Sentential Form 4-4	4.6.2	Type 2 or Context Free Grammar 4-46
4.2.2(B)	Parse Tree 4-4	4.6.3	Type 1 or Context Sensitive Grammar 4-46
4.2.3	Writing Grammar for a Language 4-6	4.6.4	Type 0 or Unrestricted Grammar 4-47
4.2.3(A)	Union Rule for Grammar 4-10	4.6.5	Derivation Graph 4-47
4.2.3(B)	Concatenation Rule for Grammar 4-10	4.7	Regular Grammar 4-47
		4.7.1	DFA to Right Linear Regular Grammar 4-47
		4.7.2	Right Linear Grammar to DFA 4-48



<p>4.7.3 DFA to Left Linear Grammar..... 4-49</p> <p>4.7.4 Left Linear Grammar to DFA..... 4-51</p> <p>4.7.5 Right Linear Grammar to Left Linear Grammar..... 4-52</p> <p>4.7.6 Left Linear Grammar to Right Linear Grammar..... 4-53</p> <p>4.8 Pumping Lemma for CFG..... 4-58</p> <p>4.9 Properties of Context-free Languages 4-60</p> <p>4.9.1 Closure Properties 4-60</p> <p>4.9.1(A) CFL is Closed under Union..... 4-60</p> <p>4.9.1(B) CFL is Closed under Concatenation 4-60</p> <p>4.9.1(C) CFL is Closed under Kleene Star 4-61</p> <p>4.9.1(D) CFL is not Closed under Intersection..... 4-61</p> <p>4.9.1(E) CFL is not Closed under Complementation 4-61</p> <p>4.9.1(F) Intersection of CFL and RL..... 4-62</p> <p>4.9.1(G) CFL is Closed under Reversal 4-62</p> <p>4.9.2 Algorithmic Properties (Decision Properties) 4-62</p> <p>4.10 Applications of CFG 4-62</p> <p>4.10.1 Parsers 4-63</p> <p>4.10.2 Markup Languages..... 4-63</p> <p>4.10.3 XML and Document-Type Definitions 4-63</p> <p>4.11 Cock-Younger-Kasami Algorithm 4-64</p> <p>4.12 University Questions and Answers..... 4-64</p>	<p>Chapter 5 : Pushdown Automata (PDA) 5-1 to 5-34</p> <hr/> <p>5.1 Introduction to Pushdown Automata (PDA) 5-1</p> <p>5.2 The Formal Definition of PDA..... 5-2</p> <p>5.3 Instantaneous Description of a PDA 5-4</p> <p>5.4 The Language of a PDA..... 5-6</p> <p>5.4.1 Acceptance by Final State..... 5-6</p> <p>5.4.2 Acceptance by Empty Stack..... 5-6</p> <p>5.5 Non-deterministic PDA (NPDA).....5-15</p> <p>5.6 Pushdown Automata and Context Free Language5-19</p> <p>5.6.1 Construction of PDA from CFG5-19</p> <p>5.6.2 Construction of CFG from PDA5-22</p> <p>5.7 Deterministic Push Down Automata (DPDA).....5-29</p> <p>5.7.1 Regular Language and DPDA.....5-29</p> <p>5.8 Application of PDA.....5-30</p> <p>5.9 Parsing.....5-30</p> <p>5.9.1 Top-Down Parsing.....5-30</p> <p>5.9.2 Bottom-Up Parsing.....5-32</p> <p>5.10 Differentiate between FA and PDA.5-33</p> <p>5.11 University Questions and Answers5-33</p>
--	---

**Chapter 6 : Turing Machine (TM) 6-1 to 6-32**

6.1	Introduction to Turing Machine.....	6-1
6.2	The Formal Definition of Turing Machine.....	6-3
6.2.1	A String Accepted by TM.....	6-3
6.2.2	Instantaneous Descriptions for Turing Machines.....	6-5
6.3	Turing Machines as Computer of Functions.....	6-17
6.4	Extension of Turing Machine.....	6-26
6.4.1	Two-way Infinite Turing Machine.....	6-26
6.4.2	A Turing Machine with Multiple Heads.....	6-26
6.4.3	Multi-Tape Turing Machine.....	6-26
6.4.3(A)	Composite TM.....	6-28
6.4.4	Non-Deterministic Turing Machine.....	6-28
6.5	Universal Turing Machine.....	6-29
6.6	Linear Bounded Automata.....	6-30
6.7	Difference between FA and TM.....	6-30
6.8	University Questions and Answers.....	6-31

Chapter 7 : Undecidability and Intractable Problems 7-1 to 7-25

7.1	Recursively Enumerable and Recursive Language.....	7-1
7.1.1	Turing Acceptable Language.....	7-1

7.1.2	An Un-decidable Problem that is RE (Recursively Enumerable).....	7-5
7.2	Enumerating a Language.....	7-5
7.2.1	Finite and Infinite Sets.....	7-6
7.3	Chomsky Hierarchy.....	7-8
7.3.1	Type 3 or Regular Grammar.....	7-8
7.3.2	Type 2 or Context Free Grammar.....	7-8
7.3.3	Type 1 or Context Sensitive Grammar.....	7-8
7.3.4	Type 0 or Unrestricted Grammar.....	7-8
7.3.5	Compare Type 0, Type 1, Type 2 and Type 3 Grammars.....	7-9
7.4	Un-decidability.....	7-9
7.4.1	Halting Problem of a Turing Machine.....	7-10
7.4.2	Un-decidability of Post Correspondence Problem.....	7-11
7.4.3	Modified PCP Problem.....	7-13
7.5	Computational Complexity.....	7-14
7.5.1	P and NP-class Problem.....	7-14
7.5.2	Intractable Problems.....	7-15
7.6	The Classes P and NP.....	7-15
7.6.1	Problem Solvable in Polynomial Time.....	7-15
7.6.2	An Example : Kruskal's Algorithm.....	7-15
7.6.3	Minimal Spanning Tree.....	7-16



7.6.4	Kruskal's Algorithm.....	7-16	7.8.1	NP-Completeness of the SAT Problem.....	7-20
7.6.5	Kruskal's Algorithm using a Turing Machine.....	7-17	7.9	A Restricted Satisfiability Problem.....	7-20
7.6.6	Polynomial-Time Reduction	7-17	7.9.1	Normal Forms for Boolean Expressions.....	7-20
7.6.7	NP-Complete Problems	7-18	7.9.2	Converting Expressions to CNF.....	7-20
7.7	An NP-Complete Problem	7-18	7.9.3	Clique Problem is NP-Complete	7-21
7.7.1	The Satisfiability Problem (SAT)	7-18	7.9.4	The Problem of Independent Sets.....	7-22
7.7.2	Traveling Salesman Problem (TSP).....	7-18	7.9.5	The Node-Cover Problem.....	7-22
7.7.3	Tractable and Intractable	7-18	7.9.6	The Directed Hamilton-Circuit Problem.....	7-23
7.7.4	3-SAT Problem.....	7-19	7.9.7	Undirected Hamiltonian Circuit.....	7-23
7.8	Representing SAT Instances	7-19	7.10	University Questions and Answers	7-24
