Course Code: CSE 228	**CIE Marks: 60**
Course Title: Theory of Computation	**SEE Marks: 40**
Credits: 3	

Course Syllabus:

Introduction: Formal language theory, Formal proof, Inductive proofs and Central concepts of automata theory.

Finite Automata: Deterministic finite automata, Nondeterministic finite automata, Finite automata with ε-transitions, Equivalence and conversion of deterministic and nondeterministic finite automata.

Regular Expressions and Languages: Regular expressions, Algebraic laws for regular expressions, Regular languages, Pumping lemma, Closure and Decision properties of regular languages.

Context Free Grammar and Languages: Context free grammars, Parsing (or derivation) and parse trees, Ambiguity in grammars and languages, context-free grammars, Pumping lemma for CFL's, Closure and Decision properties of CFL's.

Push Down Automata: Push down automata, Acceptance by empty store and final state, Equivalence between pushdown automata and context-free grammars, Deterministic push down automata. **Turing Machines:** Turing machines, the church-Turing machine, Techniques for Turing machine construction, Configurations, Computing with Turing machines, Restricted Turing machines, Turing machines and computers, Combining Turing machines.

Undecidability: Recursively enumerable language, The undecidability of the halting problem, Undecidable problems about Turing machines, Post's correspondence problem.

Complexity Theory: The classes P, NP, examples of problems in these classes. P versus NP question. NP completeness, Polynomial time reducibility, The Cook-Levin theorem. Examples of NP complete problems: Vertex cover problem, Hamiltonian path problem. Approximation algorithm, Probabilistic algorithms

Course Rationale/Description:

Central to the theory of computation are the concepts of automata, formal languages, grammar, algorithms, computability, decidability, and complexity. Why study theory when the current focus of Computer Science (and all the more so for Information Systems) is on technology and the pragmatic areas of knowledge concerned with the development and management of computer information systems? The reasons are manifold. Theory provides a simple, elegant view of the complex machine that we call a computer. Theory possesses a high degree of permanence and stability, in contrast with the ever-changing paradigms of the technology, development, and management of computer systems. Further, parts of the theory have direct bearing on practice, such as Automata on circuit design, compiler design, and search algorithms; Formal Languages and Grammars on compiler design; and Complexity on cryptography and optimization problems in manufacturing, business, and management. Last, but not least, research-oriented students will make good use of the theory studied in this course.

Course Objective

To provide a solid conceptual understanding of the fundamentals of computation. More specifically,

- To learn the basic concepts of computation and concepts of automata.
- To learn the structure of formal languages and grammar.
- To learn how to design Finite Automata for different Regular Expressions and Languages
- Learn how to solve various problems of applying normal form techniques, push down automata and Turing Machines
- To learn how to construct context free grammar for various languages.

Course Learning Outcome: (at the end of the course, students will be able to do:)

CLO1	Able to **describe** the basic concepts of formal languages of finite automata techniques
CLO2	Able to apply **design principles** in Finite Automata for different Regular Expressions and Languages
CLO3	Able to **demonstrate ability** to develop context free grammar for various languages
CLO4	Able to **synthesis problem and solutions** in various problems of applying normal form ques, push down automata and Turing Machines

Content of the course:

SL	**Course Content (as summary)**	Hrs	CLO's
1	Basic concepts of formal languages of finite automata techniques	5	CLO-1
2	Design Finite Automata for different Regular Expressions and Languages	7	CLO-2
3	Construct context free grammar for various languages	13	CLO-3
4	Solve various problems of applying normal form techniques, push down automata and Turing Machines	20	CLO-3 CLO-4

Mapping of Course Learning Outcomes to Program Learning Outcomes [attainment level used for CLO's from 1(weak)-3(strong) correlation]

PLO's CLO's	PLO 1	PLO 2	PLO3	PLO4	PLO5	PLO6	PLO7	PLO8	PLO9	PLO PLO 10 11	PLO 12
CLO1	✔										
CLO2			✔								
CLO3		✔									
CLO4					✔						

Mapping Course Learning Outcome (CLOs) with the Teaching-Learning and Assessment Strategy:

CLO's	**Teaching Learning Strategy [course teacher will decide based on the type of the contents]**	**Assessment Atrategy**	**Corresponding PLO number**	**Domain Level/ Learning Taxonomy**
CLO-1	Brainstorming sessions, Classroom discussion, Voice over PPT, Lecture video, Lecture note, Open discussion	**Class Test/Assignment/ Midterm examination**	**PLO-1**	**L1**
CLO-2	Brainstorming sessions, Classroom discussion, Voice over PPT Lecture video, Lecture note, Open discussion	Classroom discussion, Midterm examination	PLO-3	L2, L3
CLO-3	Brainstorming sessions, Classroom discussion, Voice over PPT Lecture video, Lecture note, Open discussion	Class Test/Assignment/ Final examination	PLO-2	L2
CLO-4	Brainstorming sessions, Classroom discussion, Voice over PPT Lecture	Class Test/Assignment/	PLO-5	L5

	video, Lecture note, Open discussion	Final examination		

Week/Lesson (hour)	**Discussion Topic and Book Reference**	**Student Activities during Online and Onsite and TLA**	**Mapping with CLO**	**Assessment Plan**
Week-1 Lesson 1 & 2 [2.5 Hours]	**Lesson 1:** Introduction, Formal language theory, Formal proof, Inductive proofs [Textbook, Chapter-1, Page (1-22)]		CLO1-PLO-1	
	Lesson 2: Central concepts of automata theory **(Alphabet, String, Length of String, Power of an Alphabet, Concatenation of of String, Languages, Problem)** [Textbook, Chapter-1, Page (28-33)]		CLO1-PLO-1	
Week-2 Lesson 1 & 2 [2.5 Hours]	**Lesson 1:** Finite Automata, Deterministic Finite Automata (DFA) -Formal definition, simpler notations (state transition diagram, transition table) [Reference Book-1, Chapter-3, Page (71-77)] [Textbook, Chapter-2, Page (37-52)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1	CLO1-PLO-1	Class Test, Assignment, Final Exam
	Lesson 2: Language Representation Using DFA [Textbook, Chapter-2, Page (52-55)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; **TLA1; TLA2**	CLO1-PLO-1	Class Test, Assignment, Final Exam

Week-3	**Lesson 1:** Nondeterministic Finite Automata (NFA)- Definition of NFA, language of an NFA, [Textbook, Chapter-2, Page (55-60)]			
	Lesson 2: Equivalence of Deterministic and Nondeterministic Finite Automata, Applications of Finite Automata. [Textbook, Chapter-2, Page (60-71)			
Week-4 Lesson 1 & 2 [2.5 Hours]	**Lesson 1:** Finite Automata with Epsilon Transitions, Eliminating Epsilon transitions. **[**Textbook, **Chapter-2, Page (72-80)]**	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; **TLA1; TLA2**	CLO-2 -PLO-3	Class Test, Assignment, Final Exam
	Lesson 2: Minimization of Deterministic Finite Automata, Finite automata with output (Moore and Mealy machines) and Inter conversion. **[Ref. Book-1, Chapter-3, Page (71-73, 84-101)]**	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO2 - PLO-3	
	Class Test# 1: Either online or onsite based on Wk1-Wk2 discussion. Achieve CLO1 and CLO2 [Assignment 1: Based on the discussion of Wk-2; Due: Week-5]			

Week-5 Lesson 1 & 2 [2.5 Hours]	**Lesson 1:** Introduction, Identities of Regular Expressions, Finite Automata and Regular Expressions Converting from DFA's to Regular Expressions. [Textbook: Chapter-3, Page (83-101)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA4	CLO3 - PLO-2, CLO1 - PLO-1	
	Lesson 2: Converting Regular Expressions to Automata, applications of Regular Expressions. [Textbook: Chapter-3, Page (101-108)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA4	CLO3 -PLO-2 CLO1 - PLO-1	
Week-6 Lesson 1 [2.5 Hours]	**Lesson 1:** Definition, regular grammars and FA, FA for regular grammar. [Textbook: Chapter-4, Page (125-126)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO3 PLO-2, CLO1 - PLO-1	
Week-7 Lesson 1 2.5 Hours]	Lesson 1: Regular grammar for FA. Proving languages to be non-regular - Pumping lemma [Textbook: Chapter-4, Page **(126-127)]**	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO3 -PLO-2, CLO1 - PLO-1	
	Presentation 1: Topics will be provided as Individual or Group			

Week-8 Lesson 1 & 2 [2.5 Hours]	Lesson 1: Applications of Pumping lemma Closure properties of regular languages. [Textbook: Chapter-4, Page (127-131)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO3 - PLO-2, CLO1 - PLO-1	
	Lesson 2: Introduction to Context Free Grammars and Language, Definition of Context Free Grammars, Derivation [Textbook: Chapter-5, Page (169-172)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO3 - PLO-2, CLO1 - PLO-1	
Week-9 Lesson 1 & 2 [2.5 Hours]	Lesson 1: Derivation Trees, Sentential Forms. [Textbook: Chapter-5, Page (173-179)]			
	Lesson 2: Rightmost and Leftmost derivations of Strings. Ambiguity in CFG's. [Textbook: Chapter-5, Page (175-177)]			
	Class Test# 2: Either online or onsite based on Wk3-Wk4 discussion. Achieve CLO1 and CLO3			
Week-10 Lesson 1 & 2 [2.5 Hours]	Properties of CFL, Normal form of CFL Elimination of Useless symbols , Unit productions - Null productions, Chomsky Normal Form [Textbook: Chapter-7, Page (255-273)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO4 - PLO-5, CLO1 - PLO-1	
	Lesson 2: Minimization of CFG's, CNF, GNF. [Textbook: Chapter-5, Page (147-150)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO4 - PLO-5, CLO1 - PLO-1	

	Week – 8: Midterm Examination Syllabus: Week 1 – Week 6			
Week-11 Lesson 1 & 2 [2.5 Hours]	Lesson1:Pumping Lemma for CFL's, Enumeration of Properties of CFL (Proof's omitted). [Textbook: Chapter-6, Page (156-168)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO-3 PLO-2, CLO-4 PLO-5	
	PLesson 2: Definition of Online/Onsite, Discussion Pushdown autometa [Textbook: Chapter-6, Page (161, 168- 172)]LO-2, CLO4- PLO-5	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO-3 PLO-2, CLO-4 PLO-5	
	[Assignment 2: Modulation and Multiplexing; Due: Week-11]			
Week-12 Lesson 1 & 2 [2.5 Hours]	**Lesson 1:** Acceptance by Final State and Acceptance by Empty stack and its Equivalence. [Textbook: Chapter-10, Page (258- 264)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO4 - PLO-5	
	Lesson 2: Equivalence of CFG and PDA. [Textbook: Chapter-10, Page (264- 282)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO4 - PLO-5	
Week-13 Lesson 1 & 2 [2.5 Hours]	**Lesson 1:** Formal definition and behaviour, Languages of a TM [Textbook: Chapter-12, Page (325- 334)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO4 - PLO-5	
	Lesson 2: TM as accepters, and TM as a computer of	Online/Onsite, Discussion Using	CLO4 -	

	integer functions, Types of TMs. [Textbook: Chapter-12, Page (334- 341)]	Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	PLO-5	
Week-14 **Lesson 1 & 2** **[2.5 Hours]**	**Lesson 1:** Properties of recursive and recursively enumerable languages. [Textbook: Chapter-12, Page (341- 344)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO4 - PLO-5	
	Lesson 2: Universal Turing machine, The Halting problem. [Textbook: Chapter-12, Page (344- 346)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO4 - PLO-5	
Class Test# 3: Either online or onsite based on Wk8-Wk10 discussion. Achieve CLO3 and CLO4				
Week-15 **Lesson 1** **[2.5 Hours]**	**Lesson 1:** Undecidable problems about TMs. Context sensitive language and linear bounded automata (LBA). [Textbook: Chapter-12, Page (347- 352)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2	CLO4 - PLO-1	
Week-16 **Lesson 1** **[3 Hours]**	**Lesson 1:** Chomsky hierarchy, Decidability, Post's correspondence problem (PCP), undesirability of PCP [Textbook: Chapter-17, Page (494- 501)]	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video, H5P; TLA1; TLA2TLA2	CLO1 - PLO-1 CLO3 -PLO- 2	
Presentation 2: Topics will be provided as Individual or Group				
Week-17 **Lesson 1** **[2.5 Hours]**	**Lesson 1:** Review class on topic discussed in Week-8, Week-9, Week-10	Online/Onsite, Discussion Using Interactive content e.g. Voice over PPT, PPT, Video,	CLO1 - PLO-1 CLO3 -	

		H5P; TLA1; TLA2	PLO-2 CLO4 - PLO-5	
Week – 16: Final Examination Syllabus: Week-2, Week 8 – Week 12				

Course Delivery Plan/Lesson Delivery Plan:

Assessment Pattern:

Assessment Task	**CO,s**					**CO's Mark (Total=100)**
	CO1	**CO2**	**CO3**	**CO4**	**CO5**	
Attendance	--					7
Class Test (CT1, CT2, CT3)	--					15
Assignment	--					5
Presentation	--					8
Midterm Examination	5	10	10	0	--	25
Semester Final Examination	0	10	10	20		40
Total Mark	5	20	20	20		100

CIE – Breakup (Theory) [60 marks]

Bloom's Criteria	**Attendance (07)**	**Class Test (15)**	**Assignment (05)**	**Presentation (08)**	**Mid Exam (25)**
Remember					
Understand		05	02	02	05
Apply		05		03	05
Analyze		03	03		05
Evaluate		02			05

Create				03	05

SEE – Semester End Examination [40 marks] {Theory}

Bloom Criteria	Score for the Test
Remember	**05**
Understand	**05**
Apply	**10**
Analyze	**10**
Evaluate	**05**
Create	**05**

Textbook/Recommended Readings:

1. John E. Hopcroft, Rajeev Motwani, Jeffrey D. Ullman (2007), Introduction to Automata Theory Languages and Computation, 3rd edition, Pearson Education, India

Reference Books:

1. K. L. P Mishra, N. Chandrashekaran (2003), Theory of Computer Science-Automata Languages and Computation, 3nd edition, Prentice Hall of India, India.

2. Sipser, M. (2006). Introduction to the Theory of Computation (2nd ed.). Boston, MA: Thompson Course Technology.