| **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 Able to **describe** the basic concepts of formal languages of finite automata techniques |
| --- | --- |
| CLO2 | Able Able to apply **design principles** in Finite Automata for different Regular Expressions and Languages |
| CLO3 | Abl Able to **demonstrate ability** to develop context free grammar for various languages |
| CLO4 | Able Able to **synthesis problem and solutions** in various problems of applying normal form techniques, 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 | P  L  O  1 | P  L  O  2 | PL  O3 | PL  O4 | PL  O5 | PL  O6 | PL  O7 | PL  O8 | PL  O9 | 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  video, Lecture note,  Open discussion | Class Test/Assignment/ Final  examination | PLO-5 | L5 |

| **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)] | | Online/Onsite,  Discussion Using  Interactive content  e.g. Voice over  PPT, PPT, Video,  H5P; TLA1 | CLO1-PLO-1 | Class Test, Assignment, mid Exam |
| **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)] | | Online/Onsite,  Discussion Using  Interactive content  e.g. Voice over  PPT, PPT, Video,  H5P; TLA1 | CLO1-PLO-1 | Class Test, Assignment, mid Exam |
| **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, mid Exam |
| **Lesson 2:** Language Representation Using DFA, Exercises to design 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, mid Exam |
| **Week-3** | **Lesson 1:** Nondeterministic Finite Automata (NFA)- Definition of NFA, language of an NFA, Exercises to design NFA  [Textbook, Chapter-2, Page (55-60)] | | Online/Onsite,  Discussion Using  Interactive content  e.g. Voice over  PPT, PPT, Video,  H5P; **TLA1;**  **TLA2** | CLO1-PLO-1 | Class Test, Assignment, mid Exam |
|  | **Lesson 2:** Equivalence of Deterministic and Nondeterministic Finite Automata, Applications of Finite Automata.  [Textbook, Chapter-2, Page (60-71) | | Online/Onsite,  Discussion Using  Interactive content  e.g. Voice over  PPT, PPT, Video,  H5P; **TLA1;**  **TLA2** | CLO1-PLO-1 | Class Test, Assignment, mid Exam |
| **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, mid 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, Assignment, mid Exam |
|  | 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, exercises to represent languages using regular expression  [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 | Class Test, Assignment, mid Exam |
| **Lesson 2:** Finite Automata and Regular Expressions Converting from DFA’s to Regular Expressions.  Chapter-3, Page (101-108)] | | Online/Onsite,  Discussion Using  Interactive content  e.g. Voice over  PPT, PPT, Video,  H5P; TLA1;  TLA4 | CLO3-PLO2  CLO1-  PLO-1 | Class Test, Assignment, mid Exam |
| **Week-6**  Lesson 1 and 2  [2.5 Hours] | **Lesson 1:** 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-PLO2  CLO1-  PLO-1 | Class Test, Assignment, mid Exam |
| **Lesson 2:** 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 | Class Test, Assignment, mid Exam |
| **Week-7**  Lesson 1 and 2  [ 2.5 Hours] | Lesson 1: Regular grammar for FA.  Proving languages to be non-regular  [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 | Class Test, Assignment, mid Exam |
| Lesson 2: Pumping lemma  [Textbook: Chapter-4, Page  **(126-127)]** | |  |  | Class Test, Assignment, mid Exam |
|  | Presentation 1: Topics will be provided as Individual or Group  Class Test# 2: Either online or onsite based on Wk3-Wk4 discussion.  Achieve CLO1 and CLO3 | | | | |
| **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 | Class Test, Assignment, mid Exam |
| **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 | Class Test, Assignment, mid Exam |
|  | Midterm Examination Syllabus: Week 1 – Week8 | | | | |
| **Week-9**  **Lesson 1 & 2**  **[2.5 Hours]** | **Lesson 1:** Derivation Trees, Sentential Forms.  [Textbook: Chapter-5, Page (173-179)] | | Online/Onsite,  Discussion Using  Interactive content  e.g. Voice over  PPT, PPT, Video,  H5P; TLA1;  TLA2 | CLO3-  PLO-2,  CLO1-  PLO-1 | Class Test,  Assignment,  Final Exam |
| **Lesson 2:** Rightmost and Leftmost  derivations of Strings. Ambiguity  in CFG’s.  [Textbook: Chapter-5, Page (175-177)] | | Online/Onsite,  Discussion Using  Interactive content  e.g. Voice over  PPT, PPT, Video,  H5P; TLA1;  TLA2 | CLO3-  PLO-2,  CLO1-  PLO-1 | Class Test,  Assignment,  Final Exam |
| **Week-10**  **Lesson 1 & 2**  **[2.5 Hours]** | Lesson 1: 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 | Class Test,  Assignment,  Final Exam |
|  | 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 | Class Test,  Assignment,  Final Exam |
| **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 | Class Test,  Assignment,  Final Exam |
| Lesson 2: Definition of  Pushdown automata, Model,  Acceptance of CFL,  [Textbook: Chapter-6, Page (161, 168- 172)] | | Online/Onsite,  Discussion Using  Interactive content  e.g. Voice over  PPT, PPT, Video,  H5P; TLA1;  TLA2 | CLO-3  PLO-2,  CLO-4 PLO-5 | Class Test,  Assignment,  Final Exam |
|  | **[Assignment 2: Due: Week-12]** | | | |  |
| **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 | Class Test,  Assignment,  Final Exam |
| **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 | Class Test,  Assignment,  Final Exam |
| **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 | Class Test,  Assignment,  Final Exam |
| **Lesson 2:** TM as accepters,  and TM as a computer of  integer functions, Types of  TMs.  [Textbook: Chapter-12,  Page (334- 341)] | Online/Onsite,  Discussion Using  Interactive content  e.g. Voice over  PPT, PPT, Video,  H5P; TLA1;  TLA2 | | CLO4- PLO-5 | Class Test,  Assignment,  Final Exam |
| **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 | Class Test,  Assignment,  Final Exam |
| **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,  Assignment,  Final Exam |
| Class Test# 3: Either online or onsite based on Wk8-Wk10 discussion. Achieve CLO3 and CLO4 | | | | | |
| **Week-15**  **Lesson 1 & 2**  **[2.5 Hours]** | **Lesson 1:** Undecidable  problems about TMs.  **Lesson 2:** 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 | Class Test,  Assignment,  Final Exam |
| **Week-16**  **Lesson 1 & 2**  **[2.5 Hours]** | **Lesson 1:** Chomsky  hierarchy, Decidability, Post's  correspondence problem  (PCP),  Lesson2: 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 | Class Test,  Assignment,  Final Exam |
| 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,  H5P; TLA1;  TLA2 | | CLO1 -  PLO-1  CLO3 -  PLO-2  CLO4- PLO-5 | Class Test,  Assignment,  Final Exam |
| Week – 16: Final Examination Syllabus: Week 9 – Week 16 | | | | | |

**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.