UNIT 6

1. Turing Machine (TM) Model

- A theoretical model for computation that uses an infinite tape, a tape head, and a set of states.
- The machine operates by reading a symbol from the tape, moving based on the transition function, and writing symbols.

2. Representation of Turing Machines

- TMs are represented by a 7-tuple: (Q,Σ,Γ,δ,q0,qaccept,qreject), where:
  - Q is a finite set of states.
  - Σ\Sigma is the input alphabet.
  - Γ\Tau is the tape alphabet.
  - δ\delta is the transition function.
  - q0 is the initial state.
  - qacceptq, qreject are the accept and reject states.

3. Design of Turing Machines

- Involves defining the transition function for various input conditions.
- Each machine is designed to solve specific computational problems.

4. Linear Bounded Automaton (LBA)

- A restricted version of Turing machines where the tape is limited to the length of the input.
- LBA can decide a subset of decidable languages.

5. Power of LBA

- LBA is more powerful than finite automata but less powerful than a full Turing machine.
- It can decide context-sensitive languages.

6. Variations of TM

- Includes **non-deterministic Turing machines** (NTM), **multi-tape Turing machines**, and **oracle Turing machines**.

7. Non-Deterministic Turing Machines (NDTM)

- A machine that can transition to multiple states for a given input.
- NDTMs can solve problems more efficiently than deterministic ones in certain cases (e.g., NP-complete problems).

8. Halting Problem of Turing Machine

- The problem of determining whether a given Turing machine halts on a specific input is undecidable.

9. Post Correspondence Problem

- A decision problem that is undecidable. It involves finding a sequence of tiles that form a matching string.

10. Basic Concepts of Computability

- Deals with the question of whether a problem can be solved by a computational model (like a Turing machine).
- Classifies problems into **decidable** and **undecidable**.

11. Decidable and Undecidable Languages

- **Decidable**: Languages for which there exists a Turing machine that will halt and accept/reject every input.
- **Undecidable**: Languages for which no Turing machine can always decide membership.

12. Recursively Enumerable (RE) Language

- A language where a Turing machine will accept valid strings, but may not halt for invalid strings.
- Can be semi-decided (accepted but not always rejected).

13. Computational Complexity

- Involves measuring the **time** and **space** complexity of algorithms.
- **Time complexity**: How the running time of an algorithm scales with input size.
- **Space complexity**: How much memory is required as the input size grows.

14. Cellular Automaton

- A discrete computational model composed of a grid of cells, each in a state, which changes based on a set of rules.
- Used to simulate complex systems and parallel computing.

Important MCQ

1. What is the main component of a Turing Machine?

- A) Tape
- B) States
- C) Transition function
- D) All of the above
  Answer: D

2. In a Turing Machine, the transition function:

- A) Determines the next state
- B) Determines the direction of the head movement
- C) Determines the symbol to write
- D) All of the above
  Answer: D

3. The tape in a Turing Machine is:

- A) Infinite
- B) Finite
- C) Of fixed size
- D) Circular
  Answer: A

4. A Turing Machine is a mathematical model of:

- A) Algorithm
- B) Computation
- C) Data storage
- D) None of the above
  Answer: B

5. Which of the following is NOT part of a Turing Machine's 7-tuple representation?

- A) Set of states
- B) Input alphabet
- C) Tape length
- D) Transition function
  Answer: C

6. How is the Turing Machine's behavior determined?

- A) Through its tape content
- B) By the transition function
- C) By the input length
- D) By the machine's states
  Answer: B

7. A Turing Machine can be designed to:

- A) Perform arithmetic operations
- B) Sort a list
- C) Accept a language
- D) All of the above
  Answer: D

8. A Linear Bounded Automaton (LBA) is:

- A) A finite state machine
- B) A type of Turing Machine with limited tape
- C) More powerful than a finite automaton
- D) Both B and C
  Answer: D

9. The primary limitation of a Linear Bounded Automaton is:

- A) Its finite number of states
- B) The tape is limited to the size of the input
- C) It cannot read the tape
- D) It has no transition function
  Answer: B

10. A Non-Deterministic Turing Machine (NDTM) differs from a deterministic Turing Machine in:

- A) Multiple possible transitions for the same input
- B) Infinite tape
- C) A single transition function
- D) No halting condition
  Answer: A

11. The class of problems solvable by NDTMs is the same as the class solvable by:

- A) Finite Automata
- B) Deterministic Turing Machines
- C) Linear Bounded Automata
- D) None of the above
  Answer: B

12. The Halting Problem for Turing Machines is:

- A) Solvable by a Turing Machine
- B) Decidable for all machines
- C) Undecidable
- D) Solvable by finite automata
  Answer: C

13. The Halting Problem asks whether:

- A) A Turing Machine will halt on all inputs
- B) A Turing Machine will halt on a specific input
- C) A finite automaton will halt
- D) A Turing Machine will run forever
  Answer: B

14. The Post Correspondence Problem is:

- A) Decidable for all instances
- B) Undecidable
- C) Solvable by finite automata
- D) Solvable by context-free grammars
  Answer: B

15. A problem is considered computable if:

- A) A solution can be found in finite time by an algorithm
- B) It can be solved by a Turing Machine
- C) It can be solved by an oracle Turing Machine
- D) Both A and B
  Answer: D

16. A language is decidable if:

- A) There is no Turing Machine for it
- B) There exists a Turing Machine that halts for all inputs
- C) It can be described by a regular expression
- D) It is a subset of RE
  Answer: B

17. Which of the following is an example of an undecidable problem?

- A) Sorting numbers
- B) Determining if a Turing Machine halts
- C) Checking if a string matches a regular expression
- D) Finding the greatest common divisor
  Answer: B

18. A recursively enumerable language is:

- A) A language for which a Turing Machine can always halt and decide membership
- B) A language that is accepted by a non-deterministic finite automaton
- C) A language for which a Turing Machine will halt for valid inputs, but may run forever for invalid inputs
- D) A language that cannot be described by any algorithm
  Answer: C

19. Which of the following is an example of a recursively enumerable language?

- A) The set of all even numbers
- B) The set of all valid HTML documents
- C) The set of all solutions to the Halting Problem
- D) The set of all prime numbers
  Answer: C

20. The time complexity of an algorithm measures:

- A) The memory required to run the algorithm
- B) How the execution time increases with input size
- C) How the number of states in a Turing Machine increases
- D) None of the above
  Answer: B

21. Space complexity of an algorithm refers to:

- A) The time required to execute the algorithm
- B) The amount of memory used by the algorithm
- C) The tape length used in a Turing Machine
- D) Both A and B
  Answer: B

22. In big-O notation, O(n)O(n)O(n) means:

- A) Constant time complexity
- B) Linear time complexity
- C) Exponential time complexity
- D) Quadratic time complexity
  Answer: B

23. A decidable problem has:

- A) A polynomial-time solution
- B) A non-deterministic solution
- C) A solution that can be computed in finite time
- D) None of the above
  Answer: C

24. A multi-tape Turing Machine:

- A) Has multiple tapes and heads to read/write
- B) Is less powerful than a single-tape Turing Machine
- C) Can simulate a finite automaton
- D) Always halts
  Answer: A

25. Oracle Turing Machines are:

- A) Turing Machines with access to an external oracle
- B) A variation of multi-tape Turing Machines
- C) Used for regular language recognition
- D) Solving decidable problems only
  Answer: A

26. A cellular automaton is:

- A) A model for parallel computing
- B) A machine that models cellular division
- C) A model for distributed systems
- D) Both A and C
  Answer: D

27. Cellular automata are primarily used to:

- A) Solve optimization problems
- B) Simulate complex systems
- C) Create random numbers
- D) Test machine learning algorithms
  Answer: B

28. A rule in a cellular automaton defines:

- A) The input-output behavior of the system
- B) The new state of a cell based on its current state and neighbors
- C) The final output of the machine
- D) The configuration of the tape
  Answer: B

29. Which of the following is a characteristic of a deterministic Turing Machine?

- A) It has multiple possible transitions for the same input
- B) It always halts on valid inputs
- C) It has a single possible transition for any given input
- D) It cannot be simulated by a non-deterministic machine
  Answer: C

30. Context-sensitive languages are recognized by:

- A) Regular expressions
- B) Pushdown automata
- C) Linear Bounded Automata
- D) Finite automata
  Answer: C

31. Which of the following is an example of an undecidable language?

- A) The set of all regular languages
- B) The set of all context-free languages
- C) The set of all Turing Machine halting languages
- D) The set of all finite languages
  Answer: C

32. Decidability of a language means:

- A) A Turing Machine always halts for any input
- B) It can be solved by a finite state machine
- C) A solution exists for every possible input
- D) It can be described by a regular expression
  Answer: A

33. In non-deterministic computation, the machine:

- A) Follows a single sequence of transitions
- B) Makes a guess and verifies it later
- C) Can’t simulate a deterministic machine
- D) Uses multiple tapes
  Answer: B

34. The class P consists of problems that can be:

- A) Solved in polynomial time
- B) Solved in exponential time
- C) Decided by a Turing Machine in finite time
- D) Simulated by a finite automaton
  Answer: A

35. The NP-complete class consists of:

- A) Problems that can be solved in polynomial time
- B) Problems that are as hard as the hardest problems in NP
- C) Problems that require exponential time to solve
- D) None of the above
  Answer: B

36. Which problem is NP-complete?

- A) Sorting
- B) Knapsack problem
- C) Finding the greatest common divisor
- D) Both A and B
  Answer: B

37. The Church-Turing thesis suggests:

- A) Every algorithm can be computed by a Turing Machine
- B) Every language can be recognized by a finite automaton
- C) Every recursive language is decidable
- D) None of the above
  Answer: A

38. Which of the following is true about regular languages?

- A) They can be recognized by finite automata
- B) They can be described by context-free grammars
- C) They can be computed by a Turing Machine
- D) All of the above
  Answer: A

39. Undecidability means:

- A) There is no algorithm to decide the problem
- B) The problem can be solved by an algorithm
- C) It is solvable by a Turing Machine
- D) The problem can be solved in polynomial time
  Answer: A

40. NP-hard problems are:

- A) Problems that are at least as hard as the hardest problems in NP
- B) Problems that can be solved in polynomial time
- C) Problems that cannot be solved by a Turing Machine
- D) Both A and B
  Answer: A

41. The halting problem is a classic example of:

- A) A decidable problem
- B) An NP-complete problem
- C) An undecidable problem
- D) A problem that can be solved by finite automata
  Answer: C

42. A Turing machine can simulate:

- A) A finite automaton
- B) A pushdown automaton
- C) A linear bounded automaton
- D) All of the above
  Answer: D

43. Which of the following defines P vs NP problem?

- A) Is every problem whose solution can be verified quickly solvable quickly?
- B) Is every problem solvable in polynomial time?
- C) Can every non-deterministic polynomial-time problem be solved deterministically in polynomial time?
- D) All of the above
  Answer: A

44. Which of the following problems is in NP?

- A) Sorting
- B) Turing machine halting problem
- C) Checking if a graph is connected
- D) Graph coloring
  Answer: D

45. A language is considered regular if:

- A) It can be recognized by a finite automaton
- B) It can be recognized by a pushdown automaton
- C) It can be generated by a context-free grammar
- D) None of the above
  Answer: A

46. The Busy Beaver problem is:

- A) A decidable problem
- B) A problem that has the largest Turing Machine output
- C) Solved by finite automata
- D) None of the above
  Answer: B

47. A recursive function is:

- A) A function that calls itself in its definition
- B) A function that always terminates
- C) A function defined by an algorithm
- D) None of the above
  Answer: A

48. Co-NP is the class of problems whose complement is in NP. The class of problems in NP and Co-NP:

- A) Are equal
- B) Have no overlap
- C) Do not intersect
- D) None of the above
  Answer: A

49. NP-complete problems are:

- A) Solvable in polynomial time
- B) The hardest problems in NP
- C) Solvable by non-deterministic machines
- D) Both A and B
  Answer: B

50. The complexity class P refers to:

- A) Problems solvable in exponential time
- B) Problems solvable in polynomial time
- C) Problems solvable by finite state machines
- D) Problems solvable in logarithmic time
  Answer: B