UNIT 3

Formal Languages:

1. **Derivations and the Language Generated by a Grammar**:
    - A derivation is a sequence of production rules applied to generate a string in a language. The language generated by a grammar is the set of all strings derivable from the start symbol.
2. **Definition of a Grammar**:
    - A grammar is a formal set of rules used to define the structure of a language, consisting of:
        - A set of non-terminal symbols (e.g., NNN)
        - A set of terminal symbols (e.g., TTT)
        - A set of production rules (e.g., A→BCA \rightarrow B CA→BC)
        - A start symbol (e.g., SSS)
3. **Chomsky Classification of Languages**:
    - **Type 0 (Recursively Enumerable Languages)**: Can be recognized by a Turing machine.
    - **Type 1 (Context-Sensitive Languages)**: Can be recognized by a linear-bounded automaton.
    - **Type 2 (Context-Free Languages)**: Can be recognized by a pushdown automaton.
    - **Type 3 (Regular Languages)**: Can be recognized by a finite automaton.
4. **Languages and their Relation**:
    - The hierarchy shows the inclusion of languages from Type 3 (regular) to Type 0 (recursively enumerable), where every regular language is context-free, every context-free language is context-sensitive, and every context-sensitive language is recursively enumerable.
5. **Recursive and Recursively Enumerable Sets**:
    - **Recursive Set**: A set for which a decision procedure exists (algorithm to determine membership).
    - **Recursively Enumerable Set**: A set where a Turing machine can enumerate its elements but might not halt for non-members.
6. **Languages and Automata**:
    - **Automata** are abstract machines used to recognize languages, where:
        - Finite automata recognize regular languages.
        - Pushdown automata recognize context-free languages.
        - Turing machines recognize recursively enumerable languages.
7. **Chomsky Hierarchy of Languages**:
    - Defines a classification of formal languages based on generative power, from regular languages (simplest) to recursively enumerable languages (most powerful).

Regular Grammars:

1. **Regular Sets and Regular Grammars**:
    - A **regular set** is a set of strings that can be expressed by a regular expression or recognized by a finite automaton.
    - A **regular grammar** is a context-free grammar where the production rules are restricted to right-linear or left-linear form.
2. **Converting Regular Expressions to Regular Grammars**:
    - A regular expression can be converted into an equivalent regular grammar using rules based on the structure of the expression (e.g., concatenation, union, and Kleene star).
3. **Converting Regular Grammars to Regular Expressions**:
    - A regular grammar can be converted into an equivalent regular expression by applying the reverse process of grammar construction.
4. **Left Linear and Right Linear Regular Grammars**:
    - **Left Linear Grammar**: All production rules are of the form A→xBA \rightarrow xBA→xB or A→xA \rightarrow xA→x, where xxx is a string of terminals and BBB is a non-terminal.
    - **Right Linear Grammar**: All production rules are of the form A→BxA \rightarrow BxA→Bx or A→xA \rightarrow xA→x, where xxx is a string of terminals and BBB is a non-terminal.

Important MCQ

1. Which of the following is true about a grammar?

- a) A grammar defines only regular languages
- b) A grammar defines only context-free languages
- c) A grammar defines the structure of a language
- d) A grammar is the same as a regular expression
  Answer: C

2. Which of the following is a Type 3 language in the Chomsky hierarchy?

- a) Context-free language
- b) Regular language
- c) Context-sensitive language
- d) Recursively enumerable language
  Answer: B

3. Which automaton is used to recognize regular languages?

- a) Pushdown automaton
- b) Turing machine
- c) Finite automaton
- d) Linear-bounded automaton
  Answer: C

4. A context-sensitive language can be recognized by which of the following?

- a) Pushdown automaton
- b) Turing machine
- c) Finite automaton
- d) Linear-bounded automaton
  Answer: D

5. Which of the following is a valid production rule in a regular grammar?

- a) A→aBA \rightarrow aBA→aB
- b) A→BaA \rightarrow BaA→Ba
- c) A→aBbA \rightarrow aBbA→aBb
- d) A→ABA \rightarrow ABA→AB
  Answer: A

6. The language recognized by a Turing machine is:

- a) Context-sensitive
- b) Regular
- c) Context-free
- d) Recursively enumerable
  Answer: D

7. Which of the following is not a property of regular languages?

- a) They can be recognized by a finite automaton
- b) They can be expressed by regular expressions
- c) They can be recognized by a pushdown automaton
- d) They can be described by regular grammars
  Answer: C

8. What is the Chomsky type of the language L={anbn|n≥1}L = \{ a^n b^n | n \geq 1 \}L={anbn|n≥1}?

- a) Type 0
- b) Type 1
- c) Type 2
- d) Type 3
  Answer: C

9. Which of the following languages is context-free?

- a) {anbncn|n≥1}\{ a^n b^n c^n | n \geq 1 \}{anbncn|n≥1}
- b) {anbm|n,m≥1}\{ a^n b^m | n, m \geq 1 \}{anbm|n,m≥1}
- c) {anbn|n≥1}\{ a^n b^n | n \geq 1 \}{anbn|n≥1}
- d) {anbncn|n≥1}\{ a^n b^n c^n | n \geq 1 \}{anbncn|n≥1}
  Answer: C

10. Which of the following is true about left-linear and right-linear grammars?

- a) Both types generate regular languages
- b) Left-linear grammars generate context-free languages
- c) Right-linear grammars generate context-sensitive languages
- d) Left-linear grammars generate context-sensitive languages
  Answer: A

11. Which of the following is a valid regular expression for the language of all strings over the alphabet {a,b}\{a, b\}{a,b} that contain at least one aaa?

- a) b∗a(b∗a)∗b^*a(b^*a)^*b∗a(b∗a)∗
- b) a∗b∗a^*b^*a∗b∗
- c) (a|b)∗a(a|b)^*a(a|b)∗a
- d) a∗b∗a^*b^*a∗b∗
  Answer: C

12. Which type of automaton recognizes context-free languages?

- a) Finite automaton
- b) Pushdown automaton
- c) Turing machine
- d) Linear-bounded automaton
  Answer: B

13. The production rule S→aSb|ϵS \rightarrow aSb | \epsilonS→aSb|ϵ is an example of which type of grammar?

- a) Context-free grammar
- b) Regular grammar
- c) Context-sensitive grammar
- d) Recursive grammar
  Answer: A

14. Which of the following is not a characteristic of regular expressions?

- a) They can represent all regular languages
- b) They can be converted into finite automata
- c) They can describe context-free languages
- d) They are used to describe regular sets
  Answer: C

15. Which of the following is an example of a left-linear grammar?

- a) A→aBA \rightarrow aBA→aB
- b) A→BcA \rightarrow BcA→Bc
- c) A→aBbA \rightarrow aBbA→aBb
- d) A→ABA \rightarrow ABA→AB
  Answer: A

16. Which type of language is the set {anbn|n≥1}\{a^n b^n | n \geq 1\}{anbn|n≥1}?

- a) Regular
- b) Context-free
- c) Context-sensitive
- d) Recursively enumerable
  Answer: B

17. What is the language of the regular expression (a|b)∗(a|b)^*(a|b)∗?

- a) The set of all strings containing at least one aaa or bbb
- b) The set of all strings containing only aaa or bbb
- c) The set of all strings starting with aaa or bbb
- d) The set of all strings containing zero or more aaa's and bbb's
  Answer: D

18. What does the Kleene star in a regular expression represent?

- a) Zero or more repetitions of the preceding symbol
- b) One or more repetitions of the preceding symbol
- c) A choice between two options
- d) Concatenation of two symbols
  Answer: A

19. Which of the following is the correct conversion of the regular expression (a|b)∗(a|b)^*(a|b)∗ to a regular grammar?

- a) S→aS|bS|ϵS \rightarrow aS | bS | \epsilonS→aS|bS|ϵ
- b) S→aS|bSS \rightarrow aS | bSS→aS|bS
- c) S→Sa|SbS \rightarrow Sa | SbS→Sa|Sb
- d) S→a|bS \rightarrow a | bS→a|b
  Answer: A

20. A Turing machine can recognize which type of language?

- a) Type 1
- b) Type 2
- c) Type 3
- d) Type 0
  Answer: D

21. Which of the following is true about a recursive set?

- a) It can be decided algorithmically
- b) It can be recognized by a finite automaton
- c) It can be recognized by a Turing machine that does not halt
- d) It can only be enumerated by a Turing machine
  Answer: A

22. Which of the following is not a regular grammar?

- a) A→aBA \rightarrow aBA→aB
- b) A→BaA \rightarrow BaA→Ba
- c) A→aBbA \rightarrow aBbA→aBb
- d) A→aB|bA \rightarrow aB | bA→aB|b
  Answer: C

23. Which of the following is a characteristic of a recursively enumerable set?

- a) It can be recognized by a finite automaton
- b) It can be decided algorithmically
- c) It can be enumerated by a Turing machine but may not halt
- d) It is always a context-sensitive set
  Answer: C

24. Which of the following is an example of a right-linear grammar?

- a) A→aBA \rightarrow aBA→aB
- b) A→BcA \rightarrow BcA→Bc
- c) A→aB|ϵA \rightarrow aB | \epsilonA→aB|ϵ
- d) A→bAA \rightarrow bAA→bA
  Answer: A

25. What is the Chomsky type of the language L={anbm|n≠m}L = \{ a^n b^m | n \neq m \}L={anbm|n□=m}?

- a) Type 0
- b) Type 1
- c) Type 2
- d) Type 3
  Answer: A

26. Which of the following languages is regular?

- a) {anbn|n≥1}\{ a^n b^n | n \geq 1 \}{anbn|n≥1}
- b) {anbm|n≠m}\{ a^n b^m | n \neq m \}{anbm|n□=m}
- c) {anbm|n,m≥1}\{ a^n b^m | n, m \geq 1 \}{anbm|n,m≥1}
- d) {anbncn|n≥1}\{ a^n b^n c^n | n \geq 1 \}{anbncn|n≥1}
  Answer: C

27. Which of the following statements is true about regular languages?

- a) They are always context-sensitive
- b) They can be recognized by a finite automaton
- c) They can be described by context-free grammars
- d) They cannot be described by regular expressions
  Answer: B

28. What is the regular expression for the language of all strings over {a,b}\{a, b\}{a,b} that end with aaa?

- a) (a|b)∗a(a|b)^*a(a|b)∗a
- b) a∗(a|b)∗a^*(a|b)^*a∗(a|b)∗
- c) a∗b∗aa^*b^*aa∗b∗a
- d) (a|b)+a(a|b)^+a(a|b)+a
  Answer: A

29. What is the primary difference between regular languages and context-free languages?

- a) Regular languages can be recognized by finite automata, while context-free languages require a pushdown automaton
- b) Context-free languages are more complex than regular languages
- c) Regular languages use grammars only with terminal symbols
- d) Context-free languages use grammars with recursive rules
  Answer: A

30. What is the key feature of a regular grammar?

- a) It can have recursive production rules
- b) It generates non-context-free languages
- c) Its rules consist of a terminal symbol followed by a non-terminal symbol
- d) It is used for context-sensitive languages
  Answer: C