Algorithm and Programming

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The Course Outline

Course Outline

- **Course Title:** Preparation course for FE examination
- **Intended Participants:** University Students who are going to take ITPEC examinations
- **Course Duration:** 60 hours

The Lecture Plan

Lecture Plan: Morning Exam, Sec 1-Basic Theory, Chapter 2-Algorithms and Programming

Time	Learning Points/Keywords	Explanation Points	Method	Level	Note
10 minutes	Data structure	Multidimensional array, Static array, Dynamic array, Linear list, Unidirectional list	Verbal Explanation	**High**	
		Bidirectional list, Circular list, FIFO, LIFO, Binary tree, Complete binary tree, Balanced tree			
		Ordered tree, N-ary tree, Search tree, Binary search tree, Depth-first search			
		Breadth-first search , Pre-order, Post-order, In-order			
10 minutes	Algorithms	Flowchart (Terminal, Process, Decision, Loop limit, Selection sort, Bubble sort, Merge sort	Verbal Explanation	Medium	
		Insertion sort, Shell sort, Quick sort, Heap sort, Linear search			
		Binary search, Hash table search, Depth-first search, Breadth-first search, Shortest path search			
		String pattern matching, Recursion, Divide-and-conquer approach			
10 minutes	Programming	Indentation, Nesting depth, Naming conventions, Prohibited use of instructions	Verbal Explanation	Low	
		Increased functionality efficiency, usability, maintainability of a program			
		Main routine, Subroutine, Integer type, Real type, Boolean type, Character type			
		Abstract data type, Structure type			
10 minutes	Programming Languages	Procedural language, Object-oriented language, Script language		Medium	
10 minutes	Other languages	DTD (Document Type Definition), SGML (Standard Generalized Markup Language)	Verbal Explanation	Medium	
		SOAP (Simple Object Access Protocol), XML Schema, XHTML Basic, Modulation of XHTML			

Objectives

2.1 Data structure***

- Learn and apply approaches to and fundamental mechanisms of data structures.
- Learn and apply types and characteristics of data structures.

Keywords

2.1 Data structure***

- Multidimensional array, Static array, Dynamic array, Linear list, Unidirectional list, Bidirectional list, Circular list, FIFO, LIFO, Binary tree, Complete binary tree, Balanced tree, Ordered tree, N-ary tree, Search tree, Binary search tree, Depth-first search, Breadth-first search , Pre-order, Post-order, In-order.

Objectives

2.2 Algorithms**

- Learn and apply fundamental approaches to and methods of representation for algorithms and flowcharts.
- Learn and apply the fundamentals of typical algorithms.
- Learn and apply fundamental methods of design for algorithms.

Keywords

2.2 Algorithms**

- Flowchart (Terminal, Process, Decision, Loop limit, Selection sort, Bubble sort, Merge sort, Insertion sort, Shell sort, Quick sort, Heap sort , Linear search, Binary search, Hash table search, Depth-first search, Breadth-first search, Shortest path search, String pattern matching, Recursion, Divide-and-conquer approach

Objectives

2.3 Programming

- Learn and apply programming methods and the fundamentals of coding.
- Learn and apply fundamental grammar notation for programming languages.

Keywords

2.3 Programming

- Indentation, Nesting depth, Naming conventions, Prohibited use of instructions, Increased functionality efficiency, usability, maintainability of a program, Main routine, Subroutine, Integer type, Real type, Boolean type, Character type, Abstract data type, Structure type

Objectives

2.4 Programming Languages**

- Learn and apply types, characteristics, and fundamental description methods of programming languages.
- Learn and apply methods for program creation for C, COBOL, Java, and assembler.
- Learn and apply the usage methods for spreadsheet software.

Keywords

2.4 Programming Languages**

- Procedural language, Object-oriented language, Script language

Objectives

2.5 Other languages**

- Understand and apply types, characteristics, and fundamental description methods for typical markup languages.
- Understand the characteristics of other languages used in computers.

2.5 Other languages**

- DTD (Document Type Definition), SGML (Standard Generalized Markup Language), SOAP (Simple Object Access Protocol), XML Schema, XHTML Basic, Modulation of XHTML, XSL (eXtensible Stylesheet Language), UML (Class diagram, Sequence diagram, Object diagram, Communication diagram (Collaboration diagram), State machine diagram (Statechart diagram), Operation, Attribute, Role name)

Analyzation

Analyzation

- Analyzed 24 questions
- Covered most recent years
  - 2021 Q1 Exam
  - 2021 Q2 Exam
  - 2020 Q2 Exam

Questions

Question 1

Q1. (q1-27) When the operations below are performed on an empty stack, which of the following is the data that remains in the stack? Here, "push x" stores the data x in the stack, and "pop" retrieves data from the stack.

push 1 $\rightarrow$ push 2 $\rightarrow$ pop $\rightarrow$ push 3 $\rightarrow$ push 4 $\rightarrow$ pop $\rightarrow$ push 5 $\rightarrow$ pop

a. 1 and 3
b. 2 and 4
c. 2 and 5
d. 4 and 5

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Theme: Algorithm and Programming Category: FE

a. 1 and 3
b. 2 and 4
c. 2 and 5
d. 4 and 5

Question 2

Q2. (q1-30) When h(x) = mod(x, 97) is applied as a hash function for key x, how many keys in the range of 1 through 1000 have the same hash value as that of key 1094? Here, mod(x, 97) represents the remainder of x divided by 97.

a. 9
b. 10
c. 11
d. 12

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Theme: Algorithm and Programming Category: FE

a. 9
b. 10
c. 11
d. 12

Question 2: Answer Explanation

The key is 1094, so the hash value h(1094) = mod(1094, 97) = 27.
In the range of 1through 1000, the keys where the hash value is equal to 1094 are keys where the remainder after division by 97 is 27. The values that are applicable are multiples of 97 plus 27, and the value 27 itself. As such, the number of multiples of 97 that are included in the range of 1 through 1000 is first calculated. $1000 \div 97 = 10$ (remainder 30), and the number of multiples of 97 is 10. Since key x is a multiple of 97 plus 27, " $97 \times 10 + 27$ "gives 997, and this is within 1000. Thus, there are 10 values that are a multiple of 97 plus 27, so including 27 the number of keys where the hash value is equal to 1094 is 11.
Therefore, c) is correct.

Question 3

Q3. (q1-31) Which of the following is an appropriate explanation of the hash method?

a. It is a method for accessing a record by using a function to calculate the storage address for the record from the key value of the record.

b. It is a method for accessing a record by using the storage address for the next record that is stored inside each record.

c. It is a method for accessing a record by using the key value of a record and a correspondence table of storage addresses of records.

d. It is a method for accessing a record directly by using the key value of a record as the storage address of the record.

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Question 3: Answer Explanation: Slide I

- Hashing is a method for performing a calculation (hash function) on the key value of a record, and setting the storage location. When data is searched for, by performing the same calculation on the search key, the storage location can be directly accessed.
  Therefore, a) is appropriate.
  Also, in this method, with a hash function, the storage location of multiple items of data is sometimes the same. This is called a synonym (collision).
- b) This is an explanation concerning a method for dealing with synonyms in hashing called "chaining". With chaining, in the storage location calculated with a hash function, a pointer to synonym data is stored. Also, when a synonym occurs, the stored address is accessed one after another and the synonym address is stored in the final item of data.

Question 3: Answer Explanation: Slide II

- c), d)To calculate an address from the key value of a record, there are indirect address methods and direct address methods. An indirect method performs a calculation on a key value and converts it to an address. Hashing is an indirect address method. Direct address methods include a method that creates a table with corresponding key values and addresses which is referenced during access (c), and a method that converts a key value into an address (d).

Question 4

Q4. (q1-32) There is an array with n data elements sorted into ascending order. When a binary search is used to search for two certain values, which of the following is an expression that calculates the approximate number of comparisons?

a. $log_2 n$
b. $\frac{(log_2 n+1)}{2}$
c. n
d. n^2

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Question 4: Answer Explanation

A binary search is a search method where the subject of the search is sorted in advance and then the range of the search is reduced by repeatedly dividing it in two and searching for the required data. When the required data certainly exists in n data elements, the range of the search is repeatedly divided in half and when only one data element remains the required data is found. Here, when the range of the search is divided in half rounding is performed, so the data can be considered to be found when the number of data elements in the range of the search is one or more and less than two. At this time, if the number of comparisons is k, then $1 \leq n/2^k < 2$. If each term is multiplied by 2^k, it becomes $2^k \leq n < 2 \times 2^k$ (or $2^k \leq n < 2^{k+1}$), and by using a logarithm with a base of 2 this can be represented as $k \leq log_2 n < k + 1$. The average number of comparisons is an integer value that fulfills this expression, and is approximately $log_2 n$. Therefore, a) is correct.

Question 5

Q5. (q1-34) Which of the following is the appropriate description concerning a sorting method for data?

a. In a quick sort, a subset of data elements that are retrieved at a set interval are sorted, the interval is then further reduced, and the same operation is performed. This is repeated until the interval becomes one.

b. In a shell sort, adjacent data elements are compared and switched if the order of size is the wrong way around. This operation is then repeated.

c. In a bubble sort, an intermediate base value is decided and elements are divided into a group containing elements with a greater value and a group containing elements with a lower value. The same process is then repeated inside each group.

d. In a heap sort, an unsorted section is configured into an ordered tree, and then the greatest value or the lowest value is retrieved and moved to a sorted section. This operation is repeated, and the unsorted section becomes progressively smaller.

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Question 5: Answer Explanation: Slide I

- For sorting methods, as well as the three basic sorting methods of bubble sort, selection sort, and insertion sort, there are applied sorting methods with a reduced volume of calculations including quick sort, shell sort, and heap sort. Many of the applied sorting methods use recursive algorithms, and it is necessary to understand the basic flow of each algorithm. The heap sort is an improvement of the selection sort. The **selection sort** is a method that takes the smallest (or largest) data element from a string of data and makes it the first element, and then from the remaining data string takes the smallest (or largest) data element. A heap sort is a sorting method that is based on this selection sort and uses a tree structure called a "heap." Therefore, d) is appropriate.

Question 5: Answer Explanation: Slide II

- a) A **quick sort** is a method that is an improvement of the bubble sort. It is a method that sorts by repeatedly retrieving a single element of data for comparison and then dividing the data into a group with a value lower than that element of data and a group with a value less than that element of data. The description is of a shell sort.
- b) A **shell sort** is a method that is an improvement of the insertion sort. It is a method that retrieves data in a data string at a certain interval (gap) and makes it a subset. It then sorts each data string with an insertion sort, reduces the interval further, and sorts the data again. The description is of a bubble sort.
- c) A **bubble sort (exchange sort)** is a method that compares adjacent elements of data and swaps these elements of data if the order of size is the wrong way around. The description is of a quick sort.

Question 6

Q6. (q1-35) When a function or a procedure is called, which of the following is an appropriate data structure for the temporary storage of a return address or data during a process?

a. Binary search tree
b. Queue
c. Stack
d. Doubly-linked list

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Question 6: Answer Explanation: Slide I

- When a function or a procedure is called, the process that is running is temporarily halted, the data that is being processed is saved, and the new process is started. A process that is called later is processed first. After this process is finished, the previous process is restarted based on the saved data of the halted process. Saved data in this kind of situation must be processed with the last in first out method. A **stack** has a last in first out data structure. In a stack, the most recent data is always prioritized over older data and retrieved. Therefore, c) is correct.
- a) A **binary search tree** is a tree structure where the paths from the root to the leaves proceed so that a node with a smaller key value than the node is linked to one side and a node with a larger key value is linked to the opposite side. Consequently, a high-speed data search can be performed using a key value.

Question 6: Answer Explanation: Slide II

- b) A **queue** is a data structure that is waiting to be processed that occurs in transaction processing. This data structure is processed in a first in first out manner.
- d) A **doubly-linked list** is a data structure where each element of a series of data has two pointers that can allow forward and backward movement along the elements.

Question 7

Q7. (q1-36) For the natural number n, function $f(n)$ is recursively defined as shown below. Which of the following is the value of $f(5)$?

$f(n)$: if $n \leq 1$ then return 1
else return $n + f(n-1)$

a. 6
b. 9
c. 15
d. 25

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Question 8

Q8. (q1-39) Which of the following is an appropriate description concerning the standardization of programming?

a. The original aim is not to deny the programmer individuality, but to easily acquire the effect of optimization through a compiler.

b. The establishment of programming conventions has the effect of preventing errors that are easily made by a programmer.

c. The aim is to define rules for common points that do not depend on a programming language.

d. Standardization clearly defines the standard execution time of a program and has the effect of promoting the efficient creation of a program.

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d. Standardization clearly defines the standard execution time of a program and has the effect of promoting the efficient creation of a program.

Question 8: Answer Explanation: Slide I

- The standardization of programming aims for an improvement in the quality of programming. It sets rules for the writing of a program, and programs are created based on these rules. As such, anyone who is involved with development and maintenance can easily understand the details of a program. Also, concerning programming where mistakes are easy to make and programming where there is a danger of the occurrence of a security problem, the occurrence of such problems can be prevented by the clarification of the writing method and sharing information. Therefore, b) is appropriate.
- a) Optimization of compilation is not related to the standardization of programming.
- c) The standardization of programming generally depends on the programming language.

Question 8: Answer Explanation: Slide II

- d) Through the standardization of programming, the promotion of program creation with efficient processing is possible, but the definition of a standard execution time is not applicable.

Question 9

Q9. (q1-40) Which of the following is the appropriate description concerning the various characteristics of a program?

a. In order to implement recursive processing, the status of a running program must be recorded and controlled in an FIFO manner.

b. In order to implement a reentrant program, the program must be divided into a procedure section and a data section, and a data section must exist for each process section.

c. Serially-reusable programs can also be reentrant.

d. A program that can be executed by multiple processes simultaneously is recursive.

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c. Serially-reusable programs can also be reentrant.
d. A program that can be executed by multiple processes simultaneously is recursive.

Question 10: Answer Explanation

- A reentrant program can be executed by multiple processes simultaneously. In order to enable this, a program is divided into a procedure part and data part as in the description of b) and a data part must be held for each process.
  Therefore, b) is appropriate.
- a) A recursive process must be controlled by recording the status of a running program with LIFO (Last-In First-Out).
- c) A serially reusable program can reuse a program that is loaded into main memory without reloading it, and is not a reentrant program. However, a reentrant program is serially reusable.
- d) This is a description of a reentrant program.

Question 10

Q10. (q1-41) Which of the following is a characteristic of object-orientated programs?

a. The order of calculation is not specified by the control flow rather than by the flow of data. A series of instructions becomes executable when all input data is available.

b. Control of calculation is passed from instruction to instruction in sequence. The passing of data between instructions is performed indirectly by a reference to memory through a "variable." The definition of instructions and data is separated.

c. Data is hidden from the outside, and can be manipulated indirectly with a procedure called a method. A program is a collection of bundles of data and methods.

d. A program is composed of nested arithmetic and logical expressions, instructions (symbols of operations) that represent functions, and data. "Execution of instructions" corresponds to the "calculation (evaluation) of the values of arithmetic and logical expressions or functions."

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Theme: Algorithm and Programming Category: FE

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Question 10: Answer Explanation

- The correct description concerning object oriented programs is c). An object is a bundle of data and methods. A group of such objects is a program.
- a) This is a description concerning a data flow program.
- b) This is a description concerning a procedural program.
- d) This is a description concerning a functional program.

Question 11

Q11. (q1-42) Which of the following is an appropriate explanation of a Java servlet?

a. It is a program that is developed with Java and executed on a Web application server at the request of a client.

b. It is a program that is developed with Java and executed after being downloaded from a server.

c. It is a set of rules for handling a program developed with Java as an application component.

d. It is an interpreter that executes a program developed with Java, and has a function to execute a sort of intermediate code called bytecode.

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Question 11: Answer Explanation: Slide I

- A Java servlet is a program that is developed with the Java language and executed on a Web server. Therefore, a) is appropriate. Servlet is a composite word formed from "server" and "-let" (meaning "small") and means "small server." It is executed on a Web server at the request of a client.
- b) A Java program that is downloaded from a server and executed on the client is a Java applet. The name "applet," as with "servlet," is a composite word formed from "application" and "-let" and means a small application.
- c) Rules for handling a program developed with Java as an application component are called JavaBeans. JavaBeans is a specific mechanism for component oriented development.

Question 11: Answer Explanation: Slide II

- d) One of the characteristics of the Java language is that a module generated by compiling a source program is an intermediate code called byte code rather than a program in machine language program that depends on the CPU of the computer it runs on. Then, this intermediate code is converted by an execution environment (interpreter) called a Java VM (Virtual Machine) on the computer into machine language program appropriate for the CPU on that computer, and then executed. This mechanism achieves a feature called "multiplatform" that does not select the type of computer that a program runs on. In order to execute a Java servlet, a Java VM is installed on a Web server.

Question 12

Q12. (q1-43) Which one of the following is the most appropriate as a characteristic of XML?

a. XML adds functions to HTML for the main purpose of improving the display performance of webpages.

b. In XML, optional tags can be defined to simplify the exchange of data between information systems over a network.

c. The style languages that can be used for XML are the same as those for HTML.

d. Unlike SGML-based HTML, XML was developed based on original specifications.

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Question 12: Answer Explanation: Slide I

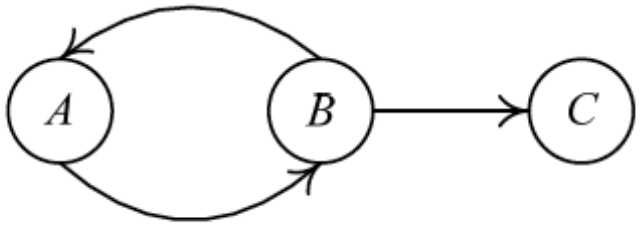
- HTML (HyperText Markup Language) is a language for the description of webpages. "Tags" enclosed in angle brackets are used to define the layout of a document. Also, by specifying a URL (Uniform Resource Locator), a document can "link" to another document. In initial development, XML (eXtensible Markup Language) was positioned as a meta-language for the exchange of structured documents on the Web, but it has progressed to a format also for the exchange of a wide range of data. In addition to the two characteristics (tags and links) of HTML, the meaning of tags can be defined with the DTD (Document Type Definition) function, and the structure of the document itself as well as the data can also be defined. For example, the tag <product info> ... </product info> can be defined and data can be represented. Therefore, b) is the most appropriate.

Question 12: Answer Explanation: Slide II

- a) XML complements the weakness of HTML, which is not suitable for the representation of data or document structure, and does not aim for improvement in the performance of webpage display.
- b) The style sheet languages that can specify the style of an XML document include XSL (eXtensible Style Language) and CSS (Cascading Style Sheets). In order to display an XML document on a Web browser, these convert XML to HTML.
- d) Like HTML, XML was developed based on SGML (Standard Generalized Markup Language). For example, the DTD function of XML is a function that SGML has.

Question 13

Q13. (2021 A FE AM-q4) An adjacency matrix is used to indicate which vertices of a directed or undirected graph are adjacent to each other. Which of the following is an appropriate matrix that represents the directed graph below?



a)

	A	B	C
A	1	1	1
B	1	1	1
C	0	0	1

b)

	A	B	C
A	1	0	1
B	0	1	0
C	1	1	1

c)

	A	B	C
A	0	1	1
B	1	0	1
C	0	0	1

d)

	A	B	C
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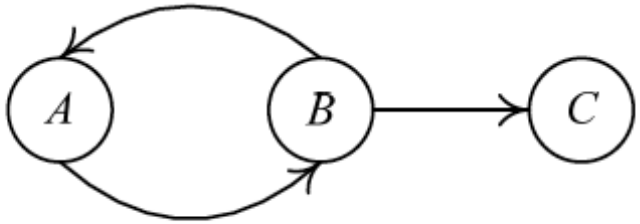

a)

	A	B	C
A	1	1	1
B	1	1	1
C	0	0	1

b)

	A	B	C
A	1	0	1
B	0	1	0
C	1	1	1

c)

	A	B	C
A	0	1	1
B	1	0	1
C	0	0	1

d)

	A	B	C
A	0	1	0
B	1	0	1
C	0	0	0

- Option d)

Question 14

Q14. (2021 A FE AM-q5) When sorting an array of n elements by using a randomized version of the quicksort algorithm, where the pivot is selected randomly, which of the following shows the averagecase and the worst-case time complexities? Here, big-O notation, O(x), is used to denote the growth rate.

	Average-case time complexity	Worst-case time complexity
a)	$O(n \log n)$	$O(n)$
b)	$O(n \log n)$	$O(n^2)$
c)	$O(n^2 \log n)$	$O(n)$
d)	$O(n^2 \log n)$	$O(n^2)$

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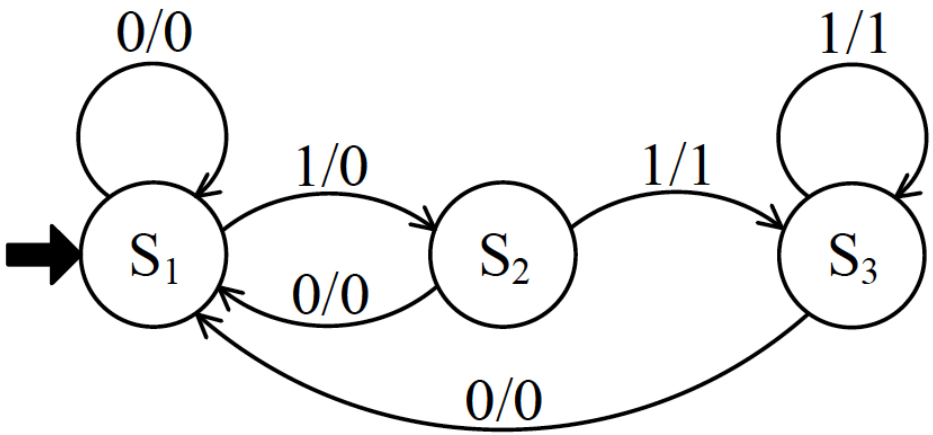
c)	$O(n^2 \log n)$	$O(n)$
d)	$O(n^2 \log n)$	$O(n^2)$

- Option b)

Question 15

Q15. (2021 A FE AM-q6) For an automaton with input and output symbols $\{0, 1\}$ and a state transition diagram shown below, which of the following is the output string for the input string 0011001110? Here, S_1 represents the initial state, and the label x/y on each arc indicates that if x is an input, then y is the corresponding output at the state transition.



a. 0001000110
b. 0001001110
c. 0010001000
d. 0011111110

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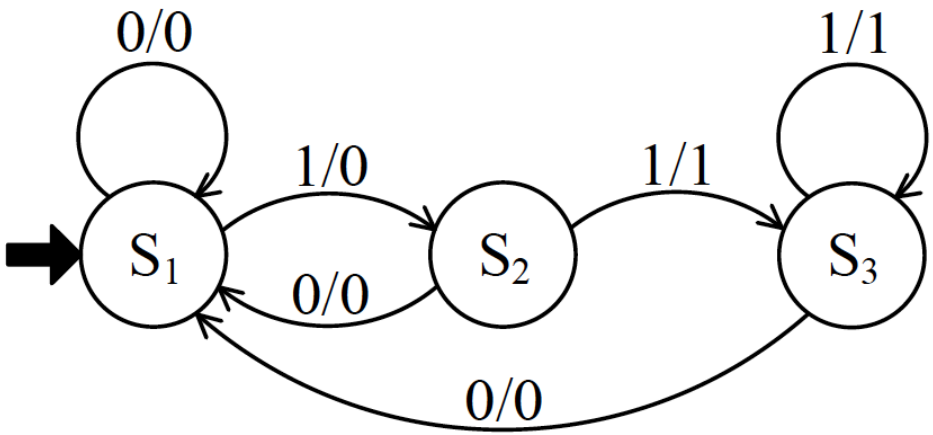

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a. 0001000110
b. 0001001110
c. 0010001000
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Question 16

Q16. (2021 A FE AM-q7) After the procedure shown below has been executed in the listed order, which value will be stored in variable y? Here, the stack and queue structures are initially empty, and the four types of operations are defined as shown below.

[Operations]

push(x):	Add the value of x onto the top of the stack.
pop():	Remove a value from the top of the stack, then return the value.
enq(x):	Add the value of x into the rear of the queue.
deq():	Remove a value from the front of the queue, then return the value.

[Procedure]

enq(1)
enq(2)
push(3)
push(deq())
enq(4)
push(deq())
$y \leftarrow$ pop()

a. 1
b. 2
c. 3
d. 4

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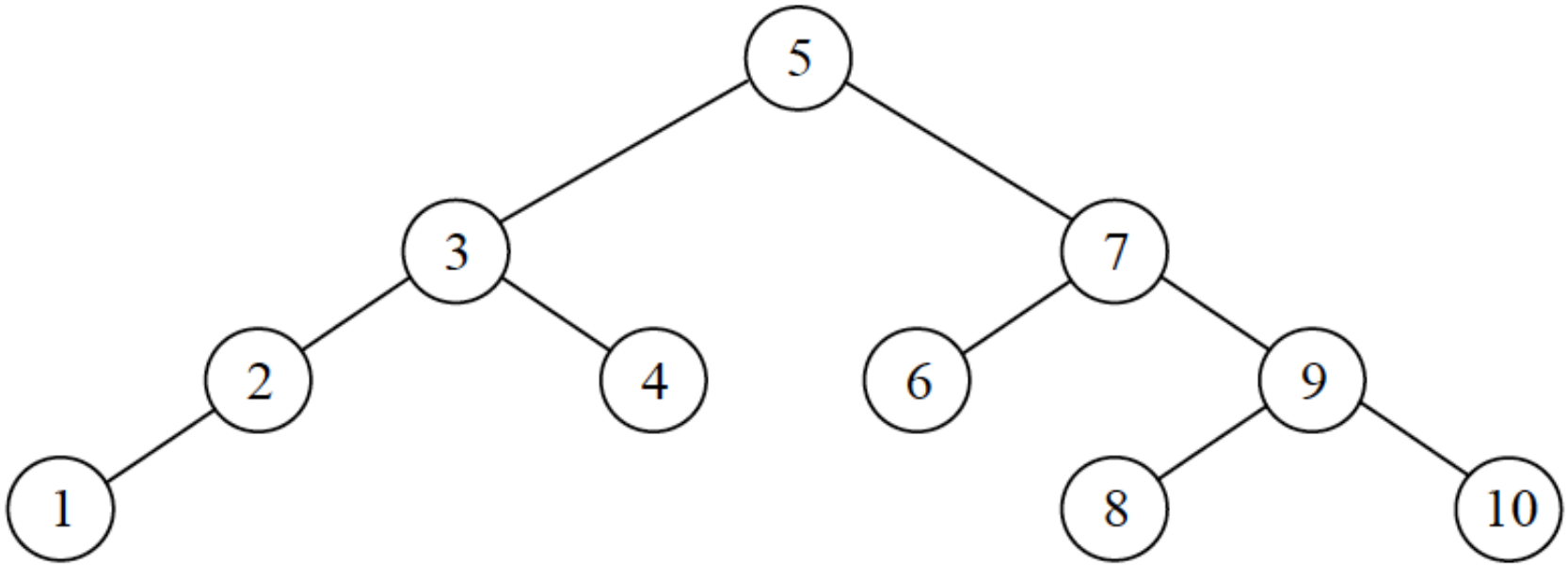
c. 3
d. 4

Question 17

Q17. (2021 A FE AM-q8) Which of the following is the name for the tree depicted below? Here, the number in each node represents the key of the node.



a. Balanced tree
b. Binary search tree
c. Max heap
d. Min heap

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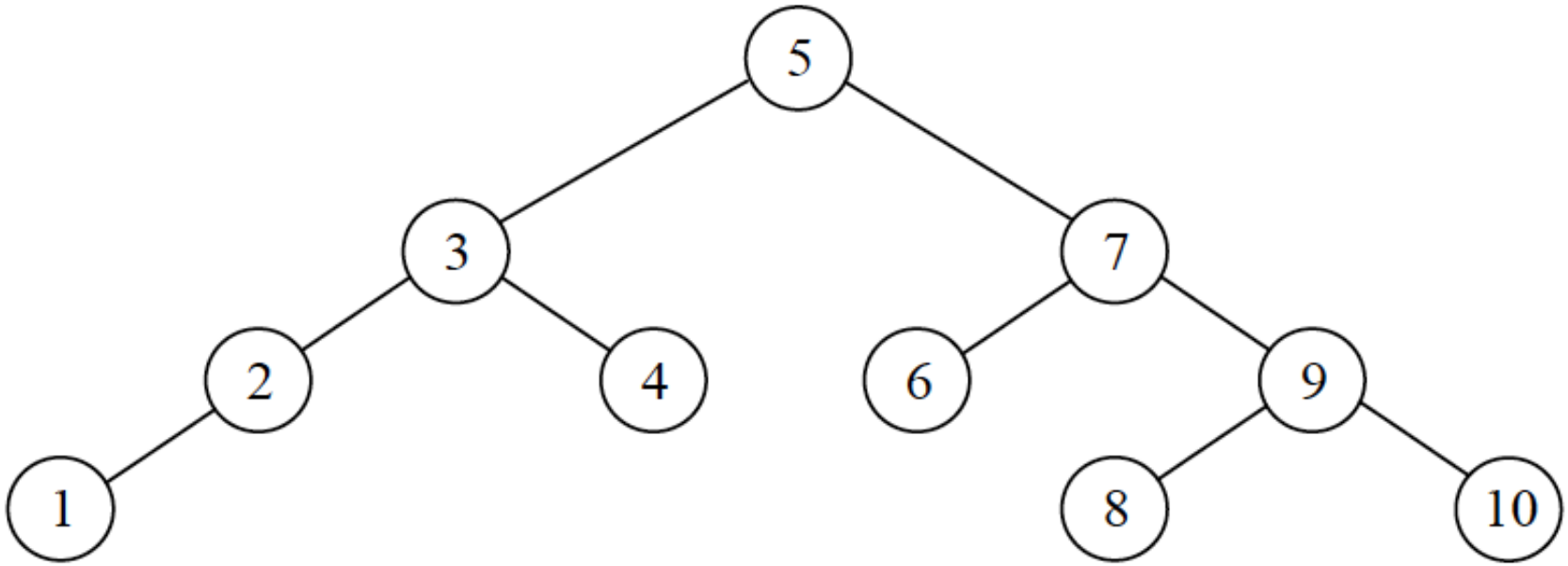

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c. Max heap
d. Min heap

Question 18

Q18. (2021 A FE AM-q9) When the function $M(n)$ is defined as shown below, what is the value of $M(97)$?

$$M(n) = \begin{cases} n - 10 & (n > 100) \\ M\,(M\,(n + 11)) & (n \leq 100) \end{cases}$$

a. 81
b. 86
c. 91
d. 96

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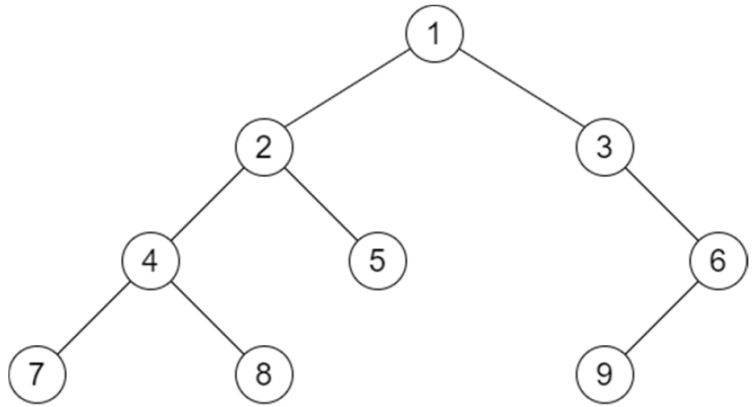
a. 81
b. 86
c. 91
d. 96

Question 19

Q19. (2021 S FE AM-q8) The in-order traversal of a binary tree is a procedure that visits all nodes of the tree. For a non-empty binary tree T, it performs the following operations in order.
(1) Recursively performs the in-order traversal of the left subtree of T.
(2) Visits the root node of T.
(3) Recursively performs the in-order traversal of the right subtree of T.
Which of the following is the ordered sequence of nodes when the in-order traversal is performed on the binary tree below?



a. 1, 2, 4, 7, 8, 5, 3, 6, 9
b. 6, 9, 3, 1, 5, 2, 8, 4, 7
c. 7, 4, 8, 2, 5, 1, 3, 9, 6
d. 7, 8, 4, 5, 2, 9, 6, 3, 1

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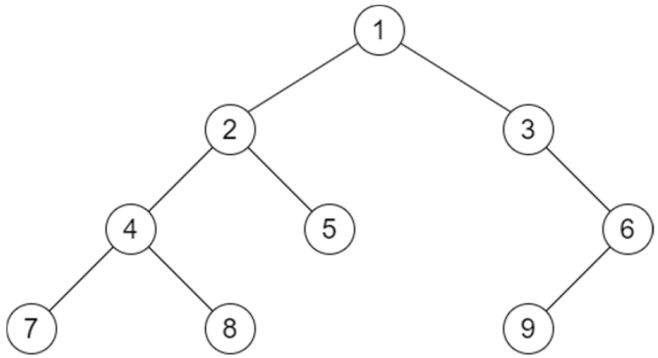

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a. 1, 2, 4, 7, 8, 5, 3, 6, 9
b. 6, 9, 3, 1, 5, 2, 8, 4, 7
c. 7, 4, 8, 2, 5, 1, 3, 9, 6
d. 7, 8, 4, 5, 2, 9, 6, 3, 1

Question 20

Q20. (2021 S FE AM-q9) Which of the following explains the objective of a recursive call?

a. To allow a function to use itself from within its body
b. To execute processes in an event-driven way rather than in a predetermined order
c. To retain a function in memory for reuse after its execution
d. To undo an execution of a process when it fails

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Question 21

Q21. (2021 S FE AM-q10) Which of the following is a technology that provides a dynamic user interface without page transition using an asynchronous communication in JavaScript?

a. Ajax
b. CSS
c. RSS
d. SNS

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Question 22

Q22. (2020 S FE AM-q6) Two operations against a queue are defined below.

- ENQ n: adds a number n at the end of the queue.
- DEQ: removes the number at the head of the queue.

For an empty queue, a sequence of operations,
"ENQ 1, ENQ 2, ENQ 3, DEQ, ENQ 4, ENQ 5, DEQ, ENQ 6, DEQ, DEQ",
is performed in this order. When another DEQ is performed in succession, what is the number to be removed by this operation?

a. 1
b. 2
c. 5
d. 6

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Theme: Algorithm and Programming Category: FE

a. 1
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Question 23

Q23. (2020 S FE AM-q7) Every year that is exactly divisible by four is a leap year, except for years that are exactly divisible by 100, but these centurial years are leap years if they are exactly divisible by 400. For example, the years 1700, 1800, and 1900 are not leap years, but the years 1600 and 2000 are. How many leap years are there between 1895 and 2021?

a. 30
b. 31
c. 32
d. 33

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a. 30
b. 31
c. 32
d. 33

Question 24

Q24. (2020 S FE AM-q8) In object-oriented programming, which of the following is an explanation of overriding that achieves polymorphism?

a. A feature that allows a class to provide a specific implementation of a method that is already provided by one of its superclasses
b. Creating a class through abstraction by collecting common properties of multiple classes
c. Defining multiple methods in a class that have the same name but differ either in the number of arguments, argument types, or argument order
d. Hiding the internal contracts and structures of an object from its external specification

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Theme: Algorithm and Programming Category: FE

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Any Questions?

References

 IT Fundamentals (New FE Textbook Vol. 1)