

**Q6.** Which of the following is an appropriate explanation of feedback control?

- a) It detects disturbance and takes a corrective action to prevent its influence.
- b) It is vulnerable to disturbance and the influence of the disturbance is amplified.
- c) It predicts disturbance and takes a corrective action accordingly.
- d) It takes a corrective action after detecting the influence of a disturbance.

**Q9.** Which of the following is an appropriate description of a binary search?

- a) A binary search is always faster than a linear search.
- b) In a binary search, searching starts from the beginning of the data.
- c) The data upon which the binary search is to be performed must be sorted.
- d) The number of comparisons that need to be performed during the search is proportional to  $\log_2 N$ , where  $N$  is the number of data items.

**Q29.** When a storage location is calculated from a key value, which of the following is the method that can produce the same calculation results from different key values?

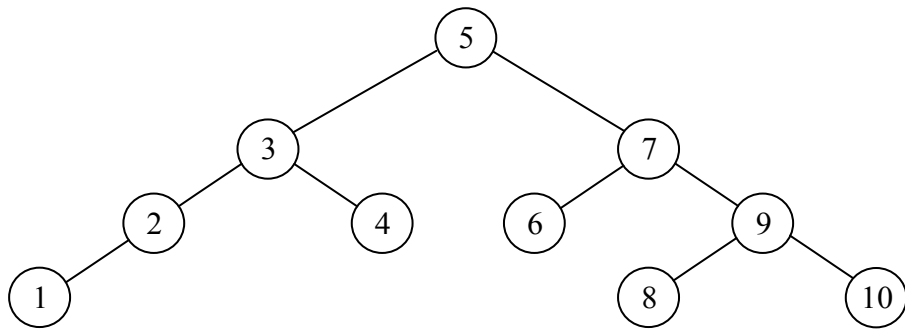
- a) B+ tree index
- b) Bitmap index
- c) Hash index
- d) Inverted index

**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 average-case 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)	$O(n^2 \log n)$	$O(n^2)$



**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
- c) Max heap

- b) Binary search tree
- d) Min heap

**Q4.** To compare the entrance exams of the current and previous years, a company required many of its employees to take those exams. The correlation coefficient and the regression line were obtained by assigning the scores of the previous year to the x-axis and the scores of the current year to the y-axis. Which of the following can be derived from the results below?

[Results]

The correlation coefficient is 0.8.

The slope of the regression line is 1.1.

The y-intercept of the regression line is 10.

- a) From the slope and the y-intercept of the regression line, the tendency is to obtain a higher score for the current year than the previous year
- b) From the slope of the regression line and the correlation coefficient, the exam of the current year is of high quality.
- c) From the slope of the regression line, the average score for the current year is 1.1 times that of the previous year.
- d) From the y-intercept of regression line, those who get zero for the current year can get a score as high as 10 for the previous year.

**Q6.** Which of the following is an appropriate description of parity check (vertical parity) that handles transmission errors on a communication line?

- a) A parity check can correct 1-bit and 2-bit errors.
- b) A parity check can detect a 1-bit error.
- c) An odd parity check can detect a 1-bit error, but an even parity check cannot even detect a 1-bit error.
- d) An odd parity check can detect any odd number of bit errors, and an even parity check can detect any even number of bit errors.

**Q9.** Which of the following explains the objective of a recursive call?

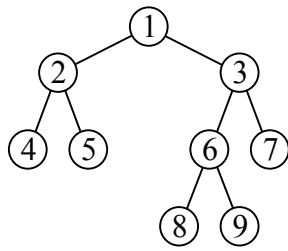
- a) To allow a function to use itself from within its body
- b) To execute processes in an event-driven way rather than in a predetermined order
- c) To retain a function in memory for reuse after its execution
- d) To undo an execution of a process when it fails

**Q5.** In machine learning, which of the following is an appropriate explanation of supervised learning?

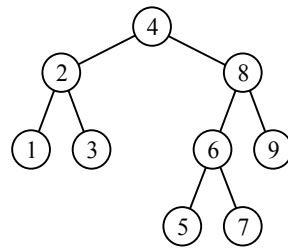
- a) Clusterizing input data according to the statistical features or specific conditions of the data without any explicit processing beforehand
- b) Learning to achieve the highest score from rating good and bad aspects of individual actions
- c) Predicting a subsequent user action from the frequency of appearances of behavioral data accumulated from computer users
- d) Training by feeding input data and their correct output so that the response to unknown data is improved

**Q6.** Which of the following is a binary search tree? Here, the number in each node represents its value.

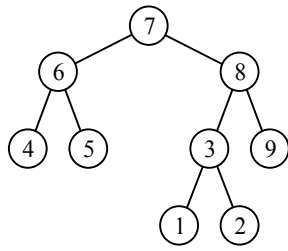
a)



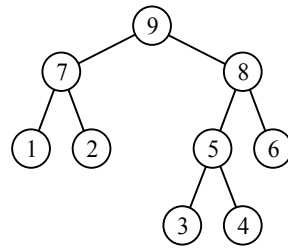
b)



c)



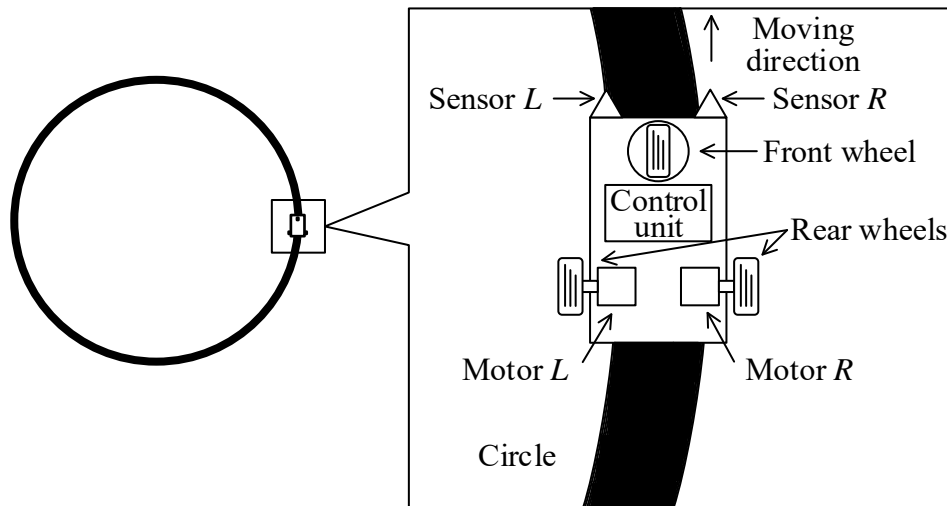
d)



**Q4.** In machine learning, which of the following best describes the supervised learning?

- a) It helps find previously unknown features or patterns on a dataset without pre-existing labels.
- b) It tries to find the best action by evaluating each result of possible actions in a specific situation.
- c) It is used to get a correct answer for new input data after being trained on a dataset with answer keys.
- d) It is used to make a prediction about the actions of a user by collecting and analyzing behavioral data.

**Q4.** A vehicle travels along a circle in the figure below. Two sensors  $L$  and  $R$  are attached to the left and right rear wheels, whose revolution speeds are independently controlled. Sensors  $L$  and  $R$  are photo reflective sensors, whose values change according to the ratio of black and white regions they pass over. If the ratio increases, the sensor value decreases, and if the ratio decreases, the sensor value increases. Which of the following is an appropriate control for ensuring that the vehicle travels along the black outline of the circle? Here, if the values of the two sensors match, the revolution speeds of the motors return to the initial speed.



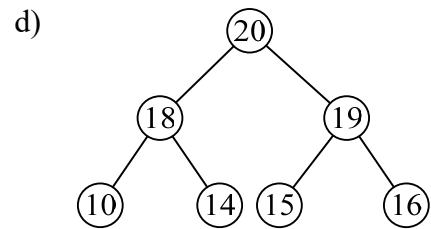
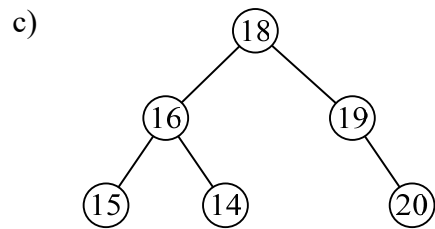
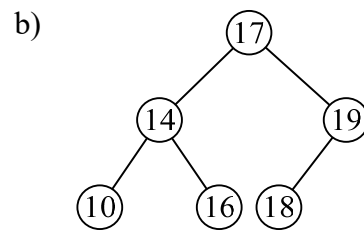
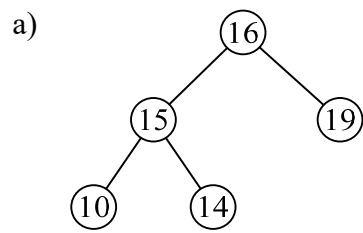
	Sensor $L$ value $>$ Sensor $R$ value		Sensor $L$ value $<$ Sensor $R$ value	
	Motor $L$ Revolution speed	Motor $R$ Revolution speed	Motor $L$ Revolution speed	Motor $R$ Revolution speed
a)	Increase	Decrease	Increase	Decrease
b)	Increase	Decrease	Decrease	Increase
c)	Decrease	Increase	Increase	Decrease
d)	Decrease	Increase	Decrease	Increase



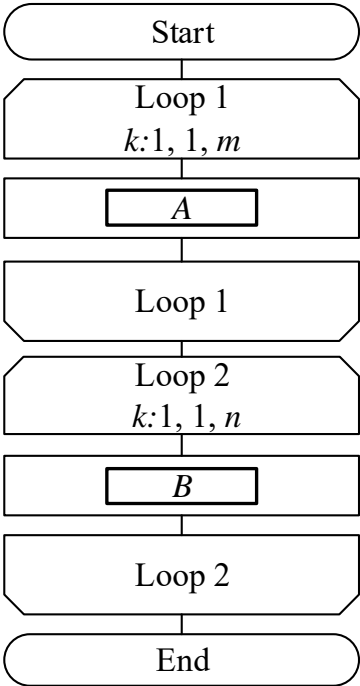
**Q7.** In a table search, which of the following is a characteristic of the search technique known as hashing?

- a) It is a method in which a collision between storage locations of data does not occur.
- b) It is a search technique that uses a binary tree.
- c) The storage locations of data are determined based on the function values of their keys.
- d) The time required to perform the search is approximately proportional to the size of the entire table.

**Q5.** Which of the following is a binary search tree?



**Q8.** The flowchart below shows the algorithm of concatenating two character strings in  $X$  and  $Y$ , with the resulting character string in  $Z$ . Which of the following is the appropriate pair of operations to insert in the blanks,  $A$  and  $B$ ? Here,  $X$  and  $Y$  are character arrays of dimensions  $m$  and  $n$ , respectively, where the  $i$ -th character of each string is stored as the  $i$ -th element of the character array.



Note:  
The description in Loop 1 indicates that variable  $k$  varies from 1 to  $m$  by 1. So does Loop 2.

	$A$	$B$
a)	$X(k) \rightarrow Z(k)$	$Y(k) \rightarrow Z(m+k)$
b)	$X(k) \rightarrow Z(k)$	$Y(k) \rightarrow Z(n+k)$
c)	$Y(k) \rightarrow Z(k)$	$X(k) \rightarrow Z(m+k)$
d)	$Y(k) \rightarrow Z(k)$	$X(k) \rightarrow Z(n+k)$

**Q4.** Which of the following is the computational complexity of the Heapsort algorithm? Here,  $n$  is the number of elements to be sorted. All comparisons, swaps, and other needed operations can proceed in constant time.

- a)  $O(\log n)$       b)  $O(n)$       c)  $O(n^2)$       d)  $O(n \log n)$

**Q6.** Data  $A$ ,  $B$ ,  $C$  and  $D$  are entered as an input sequence. Which of the following is a possible output sequence by only using a single stack?

a)  $A, D, B, C$

b)  $B, D, A, C$

c)  $C, B, D, A$

d)  $D, C, A, B$

**Q7.** For integers  $x$  and  $y$  ( $x > y \geq 0$ ), a function  $F(x, y)$  is defined as follows. What is the value  $F(231, 15)$ ? Here,  $x \bmod y$  represents the remainder after division of  $x$  by  $y$ .

$$F(x, y) = \begin{cases} x & (\text{when } y = 0) \\ F(y, x \bmod y) & (\text{when } y > 0) \end{cases}$$

a) 2

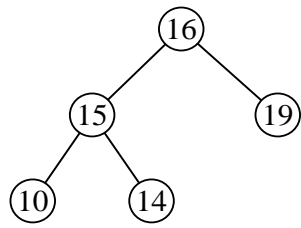
b) 3

c) 5

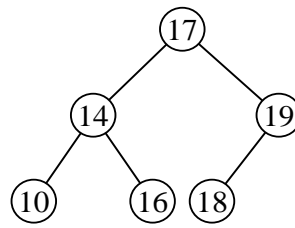
d) 7

**Q5.** Which of the following is a binary search tree whose keys are numbers assigned to nodes in natural order?

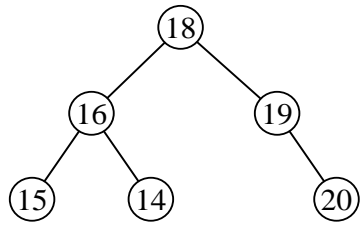
a)



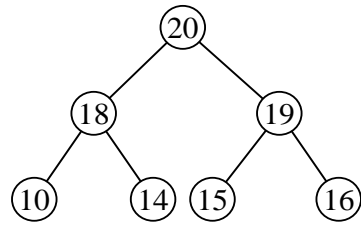
b)



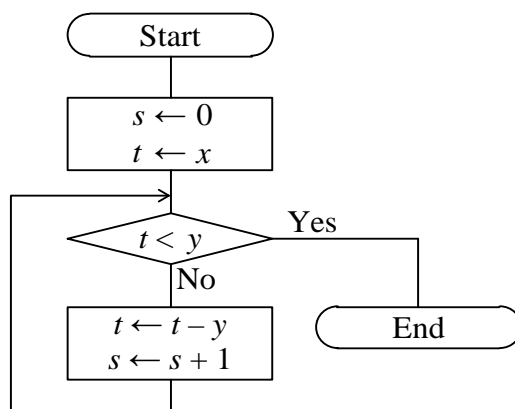
c)



d)



**Q8.** What is the result of the procedure in the flowchart below, when  $x$  and  $y$  are positive integers?



	Value of $s$	Value of $t$
a)	Remainder of $x \div y$	Quotient of $x \div y$
b)	Quotient of $x \div y$	Remainder of $x \div y$
c)	Remainder of $y \div x$	Quotient of $y \div x$
d)	Quotient of $y \div x$	Remainder of $y \div x$



**Q5.** Flowchart in Figure 1 describes a procedure to convert a matrix  $A$  to another matrix  $B$ . When this flowchart converts matrix  $A$  in Figure 2 to matrix  $B$  in Figure 3, which of the following should be filled in the blank  $C$ ? Here,  $A(i, j)$  and  $B(i, j)$  represent the  $(i, j)$ -th elements of matrices  $A$  and  $B$ . In Figure 1, the loop limits “ $k: n, m$ ” indicates the variable  $k$  to vary integers from  $n$  to  $m$ .

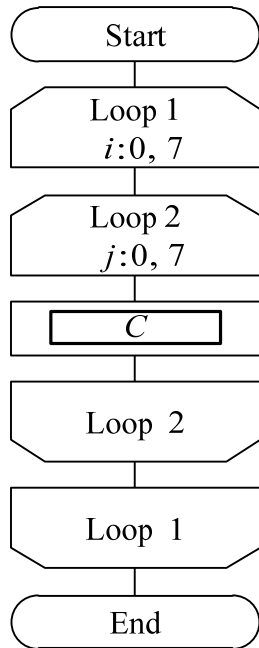


Figure 1 Flowchart

		$j$							
		0	1	2	3	4	5	6	7
$i$	0		*	*	*	*	*	*	
	1		*						
	2		*						
	3		*	*	*	*			
	4		*						
	5		*						
	6		*						
	7		*						

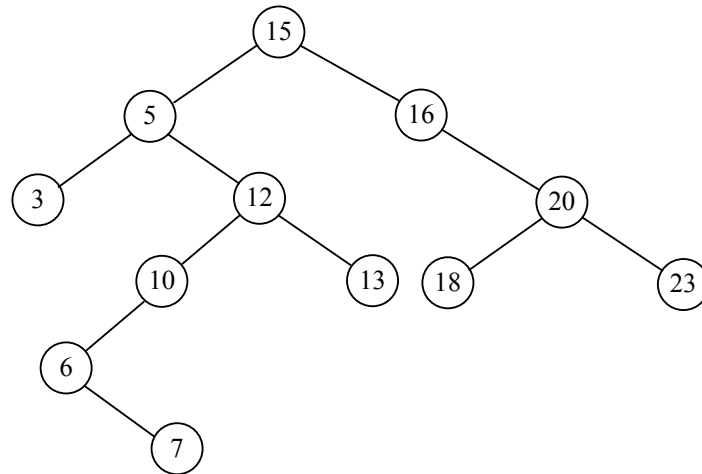
Figure 2  
Contents of matrix  $A$

		$j$							
		0	1	2	3	4	5	6	7
$i$	0								
	1	*	*	*	*	*	*	*	*
	2					*			*
	3					*			*
	4					*			*
	5								*
	6								*
	7								

Figure 3  
Contents of matrix  $B$

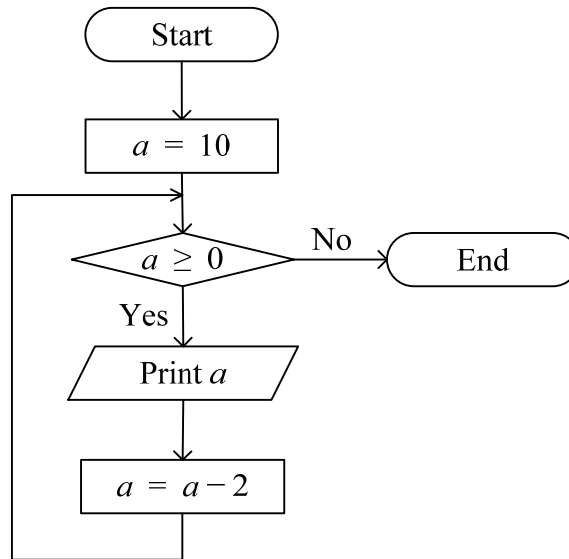
- a)  $A(i, j) \rightarrow B(7-i, 7-j)$
- b)  $A(i, j) \rightarrow B(7-j, i)$
- c)  $A(i, j) \rightarrow B(i, 7-j)$
- d)  $A(i, j) \rightarrow B(j, 7-i)$

**Q6.** In the binary tree shown below, where is the position for a new node of value 17? Here, each circle represents a node of the tree and the number in the circle represents its value.



- |                      |                     |
|----------------------|---------------------|
| a) Left child of 16  | b) Left child of 18 |
| c) Right child of 13 | d) Right child of 3 |

**Q7.** Which of the following is the output of the flowchart below?



- a) 0 1 2 3 4 5 6 7 8 9 10
- b) 0 2 4 6 8 10
- c) 10 8 6 4 2 0
- d) 10 9 8 7 6 5 4 3 2 1 0

**Q4.** A leap year is either a multiple of 4 but not a multiple of 100, or a multiple of 400. How many leap years are there from 1998 to 2110?

- a) 26                      b) 27                      c) 28                      d) 29

**Q5.** Which of the following is the most appropriate description of a queue?

- a) Data that is stored first is retrieved first.
- b) Data that is stored last is retrieved first.
- c) It references specific data by using an index.
- d) It represents the hierarchical relationship of data by using at least two (2) pointers.

**Q6.** Binary search is used to search for an element from a sorted data of  $n$  elements. Which of the following is an expression that represents the order of computational complexity for this process?

- a)  $\log n$                       b)  $n$                       c)  $n^2$                       d)  $n \log n$

**Q5.** With a randomized version of the quicksort algorithm, where the pivot is selected randomly, which of the following shows the average-case and the worst-case time complexities? Here,  $O( )$  is used to denote the order of growth rate.

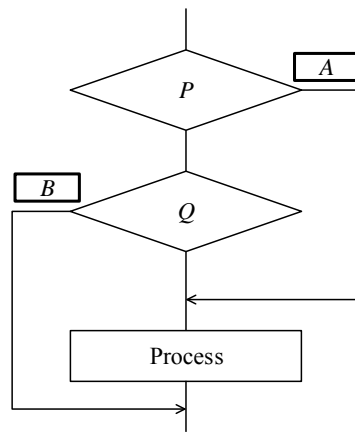
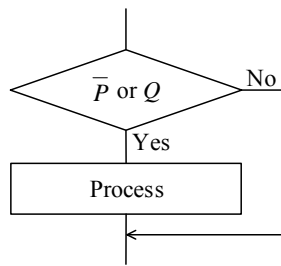
	Average-Case Time Complexity	Worst-Case Time Complexity
a)	$O(n \log n)$	$O(n)$
b)	$O(n \log n)$	$O(n^2)$
c)	$O(n^2 \log n)$	$O(n)$
d)	$O(n^2 \log n)$	$O(n^2)$

**Q8.** Typical list data type implementations are either array based or pointer based. Which of the following describes a characteristic of array-based implementations?

- a) In addition to space for each element in a list, space for a pointer to the next element is also required.
- b) Moving to the middle of a list takes an amount of time proportional to the number of elements, as it requires visiting all the entries from the beginning to the middle.
- c) Regardless of the actual number of elements in a list, insertion and removal of an element can be performed in a fixed time.
- d) Regardless of the actual number of elements in a list, some space may remain unused as the space for storing the maximum number of elements is pre-allocated.

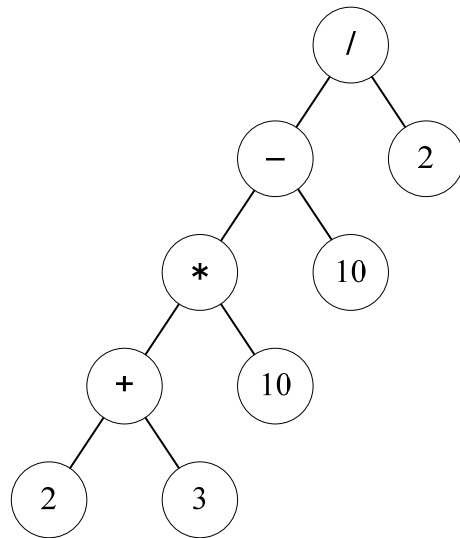


**Q9.** To make the flowcharts below equivalent, which of the following combinations is appropriate for labels  $A$  and  $B$ ? Here,  $\bar{P}$  represents the negation of  $P$ .



	$A$	$B$
a)	No	No
b)	No	Yes
c)	Yes	No
d)	Yes	Yes

**Q10.** What is the value of the arithmetic expression resulting from an in-order traversal of the binary tree below?



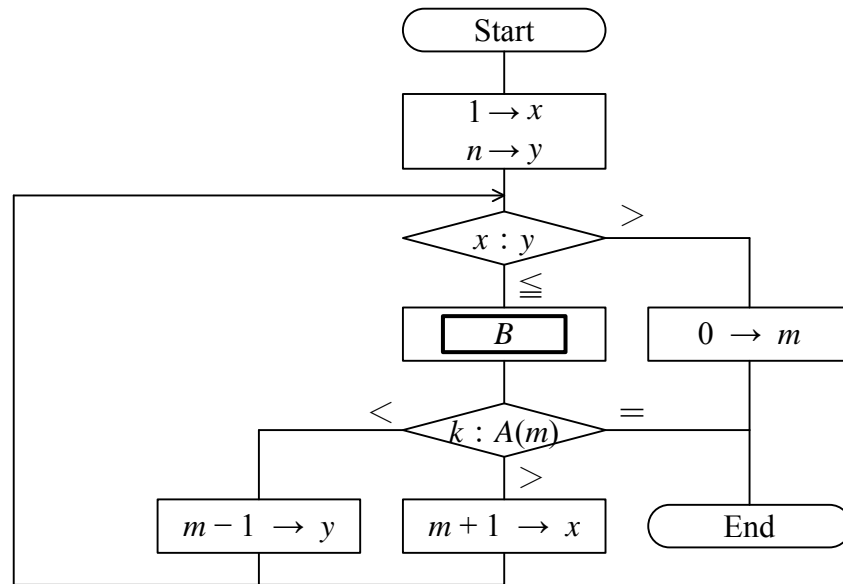
a) 11

b) 20

c) 27

d) 45

**Q9.** Let  $A$  be an array of size  $n$ , whose elements,  $A(1), A(2), \dots, A(n)$ , are in ascending order. For a value  $k$ , a procedure for finding the index  $m$  which satisfies  $A(m) = k$  is described below. If no such index is found, the procedure terminates with  $m = 0$ . Which of the following is the appropriate operation to be filled in  $B$ ? In the options, “/” denotes the quotient whose fractional part is discarded.



- |                                |                                |
|--------------------------------|--------------------------------|
| a) $(x + y) \rightarrow m$     | b) $(x + y) / 2 \rightarrow m$ |
| c) $(x - y) / 2 \rightarrow m$ | d) $(y - x) / 2 \rightarrow m$ |

**Q4.** For a balanced binary search tree, which of the following is the asymptotic time complexity of the search operation for a set of " $n2^n$ " data elements? Here, " $O( )$ " denotes the order of the algorithm's running time, and " $n$ " is sufficiently large.

a)  $O(n)$

b)  $O(n2^n)$

c)  $O(\log_2 n)$

d)  $O(n \log_2 n)$

- Q5.** When the condition and inferences are given as shown below, which of the following is the appropriate combination that supports the validity of the two inferences?

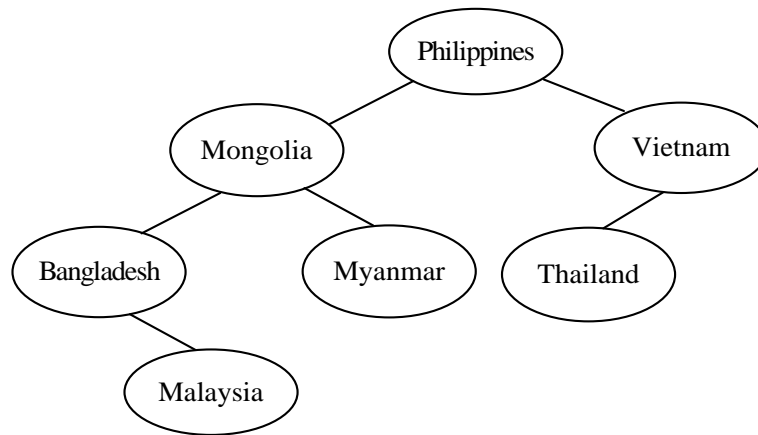
Condition: If it rains, then the street will be wet.

Inference 1: The street is not wet, and therefore, it did not rain.

Inference 2: It did not rain, and therefore, the street is not wet.

	Inference 1	Inference 2
a)	Not valid	Not valid
b)	Not valid	Valid
c)	Valid	Not valid
d)	Valid	Valid

- Q6.** As shown below, there is a binary search tree where each node contains a country name and is ordered alphabetically so that Mongolia comes before Philippines, Myanmar comes before Philippines but after Mongolia, and so on. Which of the following is the appropriate order of the country names that can create this binary search tree by inserting each country name in an empty tree?



- a) Malaysia, Bangladesh, Mongolia, Myanmar, Philippines, Vietnam, Thailand
- b) Malaysia, Bangladesh, Myanmar, Mongolia, Thailand, Vietnam, Philippines
- c) Philippines, Malaysia, Bangladesh, Mongolia, Myanmar, Thailand, Vietnam
- d) Philippines, Vietnam, Mongolia, Thailand, Bangladesh, Myanmar, Malaysia

**Q7.** In a real time system, which of the following is the data structure that is most suitable for the scheduling of multiple tasks with different priority levels?

- a) Binary tree      b) FIFO queue      c) Linked list      d) Stack

- Q9.** As shown in the table below, there are five items *A* through *E*. Each item cannot be divided into smaller pieces. When a knapsack with a maximum volume of 7 units is available for carrying the items, which of the following is a set of items to be packed in the knapsack so that the total price can be maximized?

Item	Volume	Price
<i>A</i>	3	4
<i>B</i>	2	3
<i>C</i>	3	5
<i>D</i>	1	2
<i>E</i>	5	9

- a) *A, B, D*                                      b) *A, C, D*  
c) *B, E*    d) *D, E*

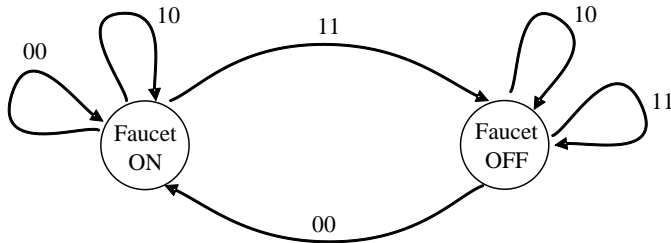


**Q3.** When the word list of a dictionary is searched for an exact matching word, which of the following is the most appropriate data structure in terms of runtime computational complexity?

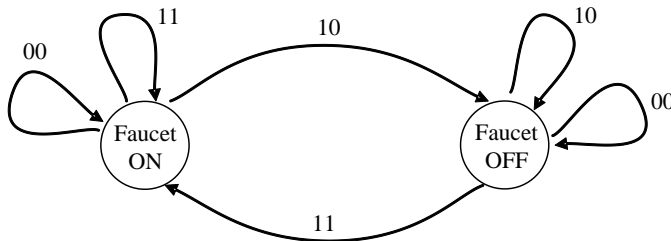
- a) Array
- b) Binary search tree
- c) Hash table
- d) Linked list

**Q4.** There is a water tank that is equipped with a faucet to fill the tank with water and two sensors (S1 and S2) to control the faucet. S1 and S2 are used to check the lower and upper limits respectively. If the water level in the tank is lower than the specified limit, the sensor indicates 0. Otherwise, the sensor indicates 1. In order to keep the water level between the lower limit and the upper limit, the faucet is opened (i.e., ON) or closed (i.e., OFF), on the basis of the signals of S1 and S2. Which of the following is an appropriate state transition diagram that shows such a situation? Here, in the diagram, the left and right bits of the 2-bit input data indicate the signals from S1 and S2 respectively.

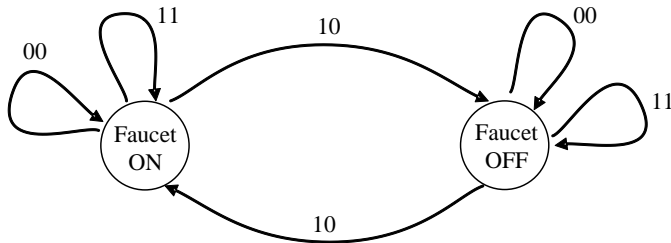
a)



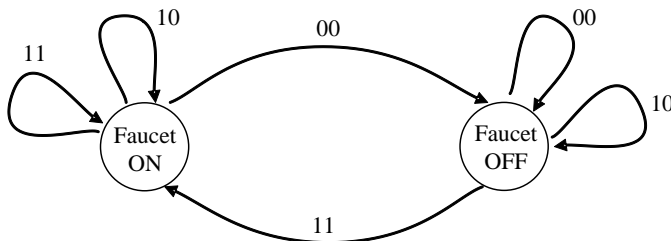
b)



c)



d)



**Q8.** There is a circular queue implemented with a one-dimensional array of  $n$  elements. Insertion and removal of data are performed by using an array index as a pointer. Two pointers  $F$  and  $R$  are respectively used for removal and insertion. Each of the two pointers is initially zero (i.e.,  $F=R=0$ ). When the queue is empty or full, which of the following is the appropriate combination of the relations between the two pointers? Here, “ $x \bmod y$ ” represents the remainder of  $x$  divided by  $y$ .

	Full queue	Empty queue
a)	$F = R$	$F = (R + 1) \bmod n$
b)	$F = (R + 1) \bmod n$	$F = R$
c)	$F = (R + 1) \bmod n$	$R = (F + 1) \bmod n$
d)	$R = (F + 1) \bmod n$	$F = R$

**Q6.** When a binary tree is a heap with a depth of “ $n$ ”, what is the minimum number of nodes (including leaf nodes) in the heap? Here, the depth of a node is the length of the path from the root to the node, and the root has depth zero.

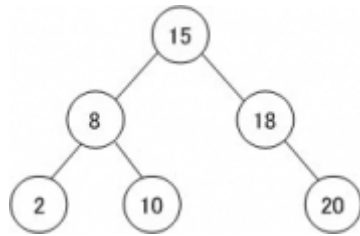
a)  $2^n$

b)  $2^n - 1$

c)  $2^{n+1}$

d)  $2^{n+1} - 1$

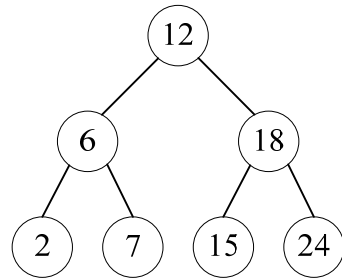
- Q7.** When the binary search tree shown below is traversed in pre-order, in-order, and post-order, which of the following is the appropriate combination of the results?



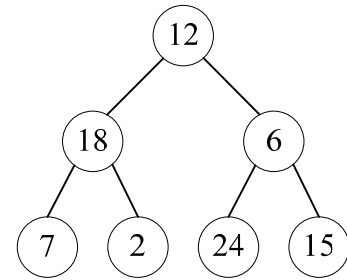
	Pre-order traversal	In-order traversal	Post-order traversal
a)	2, 8, 10, 15, 18, 20	2, 10, 8, 20, 18, 15	15, 8, 2, 10, 18, 20
b)	2, 10, 8, 20, 18, 15	15, 8, 2, 10, 18, 20	2, 8, 10, 15, 18, 20
c)	15, 8, 2, 10, 18, 20	2, 8, 10, 15, 18, 20	2, 10, 8, 20, 18, 15
d)	15, 8, 2, 10, 18, 20	2, 10, 8, 20, 18, 15	2, 8, 10, 15, 18, 20

**Q9.** Which of the following is a valid binary search tree?

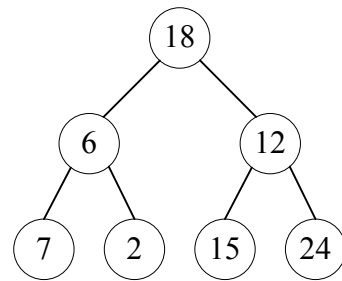
a)



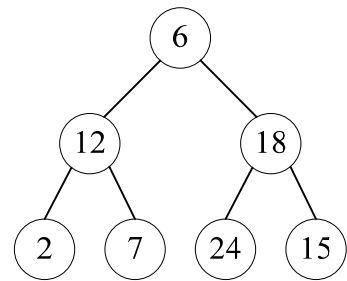
b)



c)



d)



**Q10.** Which of the following is the average time complexity of a randomized quick sort algorithm where the pivot is selected randomly? Here, " $O( )$ " denotes the order of the algorithm's running time, and " $n$ " is the number of data to be sorted.

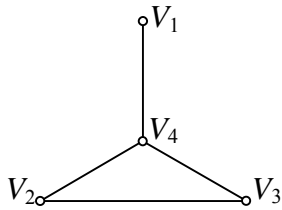
- a)  $O(n)$                       b)  $O(n^{1.5})$                       c)  $O(n^2)$                       d)  $O(n \log_2 n)$

**Q4.** Which of the following is the graph that is represented by the adjacency matrix  $A$  shown below? Here, an adjacency matrix is an  $n \times n$  matrix in which both the element of row  $i$  and column  $j$  and another element of row  $j$  and column  $i$  become “1” when an edge joining the vertices  $V_i$  and  $V_j$  of a graph consisting of the “ $n$ ” number of vertices is present, and “0” when the edge is not present.

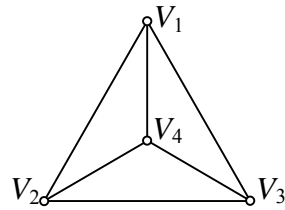
[Adjacency matrix  $A$ ]

$$\begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & 1 \\ 1 & 0 & 0 & 1 \\ 0 & 1 & 1 & 0 \end{bmatrix}$$

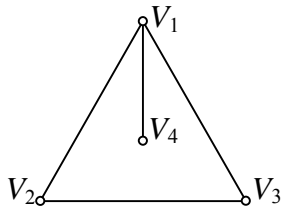
a)



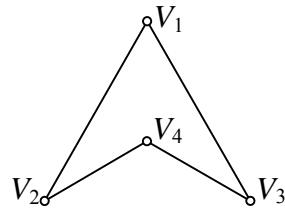
b)



c)



d)





- Q5.** When  $F(v, w)$  is defined using standard predicate logic as shown below, which of the following is the correct meaning of  $F(v, w)$ ? Here,  $P(x, y)$  means “ $x$  is a parent of  $y$ ”, and  $W(x)$  means “ $x$  is a female”. In addition, “ $\exists x \exists y P(x, y)$ ” means that there exist  $x$  and  $y$  such that  $P(x, y)$  is true.

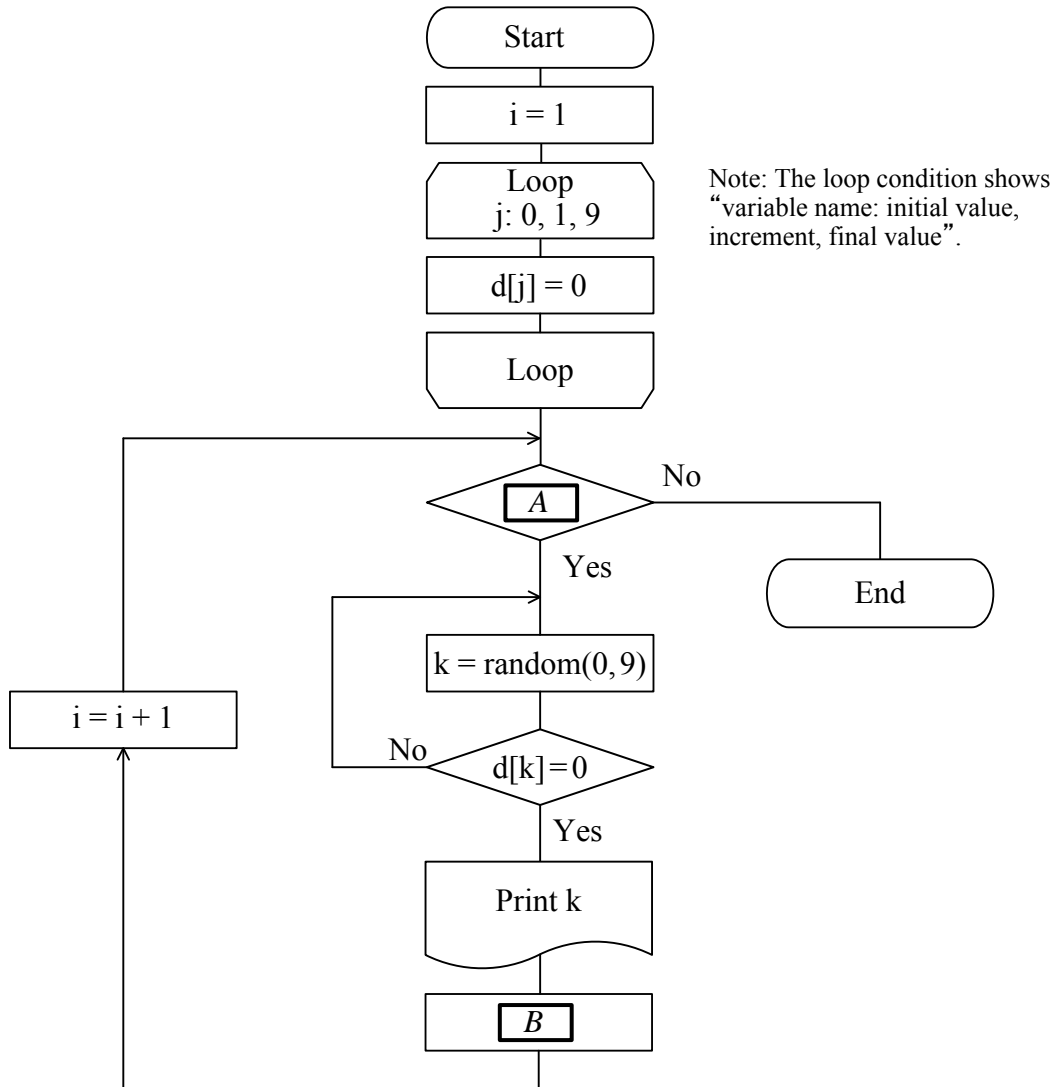
$$F(v, w) = W(v) \cap \exists x \exists y (P(x, y) \cap P(x, v) \cap (y \neq v) \cap (P(y, w)))$$

- |                                  |                            |
|----------------------------------|----------------------------|
| a) $v$ is a grandmother of $w$ . | b) $v$ is a niece of $w$ . |
| c) $v$ is a sister of $w$ .      | d) $v$ is an aunt of $w$ . |

**Q8.** Which of the following is an appropriate set of sorting algorithms that are based on the divide-and-conquer strategy?

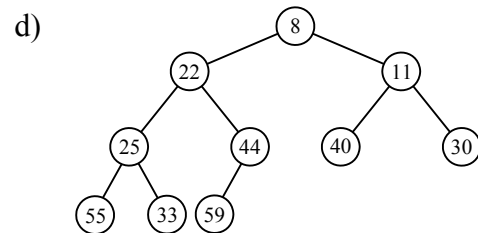
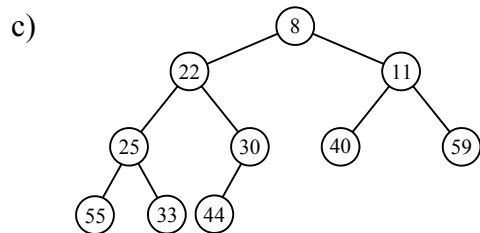
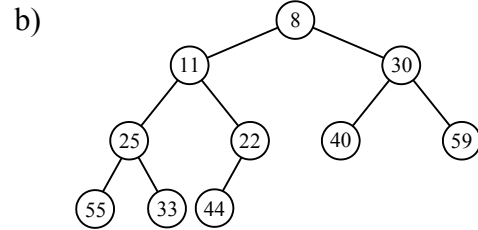
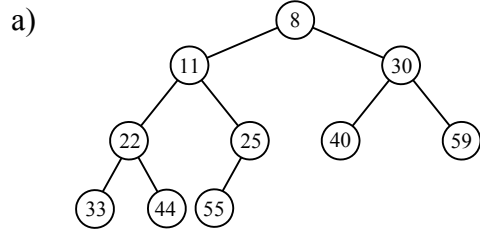
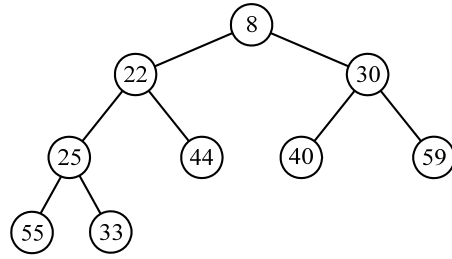
- a) Bubble sort, merge sort
- b) Heap sort, insertion sort
- c) Merge sort, quick sort
- d) Quick sort, shell sort

**Q10.** The flowchart below shows the algorithm that generates and prints a 4-digit decimal number where each digit is randomly generated and has a different decimal number. Which of the following is the correct combination of expressions that can be inserted into blanks *A* and *B* in the flowchart? Here, the function “random(0,9)” is used to generate a random decimal integer from 0 through 9. The one-dimensional array “d” consists of 10 elements d[0] through d[9].



	<i>A</i>	<i>B</i>
a)	$i < 4$	$d[k] = 0$
b)	$i < 4$	$d[k] = i$
c)	$i < 5$	$d[k] = 0$
d)	$i < 5$	$d[k] = i$

**Q7.** When “11” is inserted in the min-heap shown below, which of the following min-heaps is created? Here, a new node is first placed at the bottom (or last) of the tree, and then it is shifted up to its proper place to maintain the min-heap structure.



- Q8.** The figure below shows the structure of a singly-linked list. In order to insert Philadelphia between New York and Washington DC, which of the following is an appropriate operation to be performed? Here, “null” indicates the end of the list.

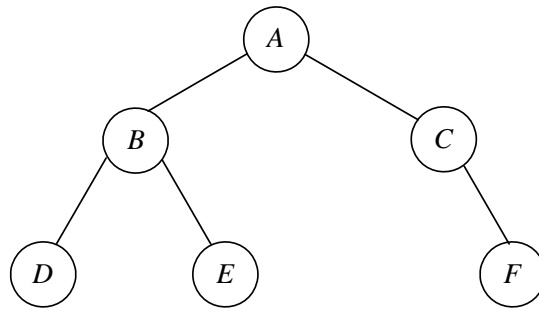
Head pointer

10
----

Address	Element	Pointer
10	Boston	50
30	Miami	null
50	New York	90
70	Atlanta	30
90	Washington DC	70
110	Philadelphia	

- a) The pointers for New York and Philadelphia are set to 90 and 110 respectively.
- b) The pointers for New York and Philadelphia are set to 110 and 50 respectively.
- c) The pointers for New York and Philadelphia are set to 110 and 70 respectively.
- d) The pointers for New York and Philadelphia are set to 110 and 90 respectively.

- Q9.** In the binary search tree shown below, which of the following is the appropriate sequence of nodes that are visited in an in-order traversal?



- a)  $A \rightarrow B \rightarrow C \rightarrow D \rightarrow E \rightarrow F$
- b)  $A \rightarrow B \rightarrow D \rightarrow E \rightarrow C \rightarrow F$
- c)  $D \rightarrow B \rightarrow E \rightarrow A \rightarrow C \rightarrow F$
- d)  $D \rightarrow E \rightarrow B \rightarrow F \rightarrow C \rightarrow A$

**Q10.** Which of the following is the appropriate description of the “selection sort” algorithm?

- a) An intermediate reference value is determined, and then the elements are divided into two groups of “larger” values and “smaller” values. This operation is recursively repeated.
- b) Each set of the elements extracted at regular intervals is sorted, and then the interval is further decreased. The operation is repeatedly performed until the interval becomes 1.
- c) The element with the largest value is determined and swapped for the last element, and then the largest value of the unsorted elements is determined and swapped for the second-to-the-last element. This operation is repeated in the same way.
- d) Two adjacent elements are repeatedly compared and swapped if the first element is larger than the second. This operation is repeated until all elements are arranged in an orderly fashion.

**Q4.** A  $k$ -string is defined as a string of length  $k$ . An  $m$ -substring is an ordered sequence of  $m$  consecutive elements of the original string. How many  $m$ -substrings are contained in a  $k$ -string? Here, when two or more  $m$ -substrings have the same sequence of elements, they are all counted separately as different substrings.

- a)  $k + m - 1$       b)  $k - m$       c)  $k - m + 1$       d)  $k - m - 1$



**Q5.** In postfix notation, also known as reverse Polish notation, which of the following is equivalent to the arithmetic expression “ $-a + b \times c \div d - e$ ”? Here,  $a$ ,  $b$ ,  $c$ ,  $d$ , and  $e$  are all variables.

a)  $a - bc \times d \div + e -$

b)  $a - b + c \times d \div e -$

c)  $bc \times a - + d \div e -$

d)  $-abc \times d \div + e -$

**Q6.** Which of the following can be accepted as  $\langle \text{root} \rangle$  that is defined using the BNF notation below? Here, the symbol “ $\epsilon$ ” represents an empty string.

$\langle \text{root} \rangle ::= \langle \text{node} \rangle$

$\langle \text{node} \rangle ::= 0 \langle \text{node} \rangle 0 \mid 1 \langle \text{node} \rangle 1 \mid 0 \mid 1 \mid \epsilon$

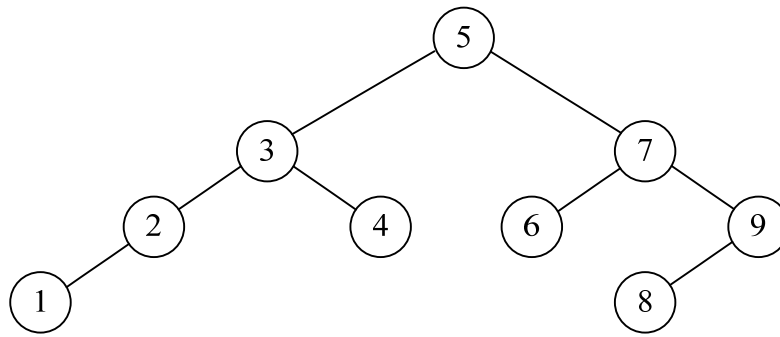
a) 0011011100

b) 01110110

c) 1001001

d) 110101111

**Q9.** What is the tree below called?



- a) Balanced tree
- c) Max heap

- b) Binary search tree
- d) Min heap

**Q7.** Which of the following is an appropriate description concerning a max heap whose node values are 3, 6, 11, 17, 19, 22, and 32?

- a) All node values at the deepest level are smaller than those at the upper level.
- b) Only one unique heap can be represented graphically.
- c) The root node value is always “32”.
- d) There is a possibility that “3” is a child of the root node.

**Q8.** Which of the following is an appropriate technique that is used for implementing a queue as a data structure?

- a) FIFO                      b) LFU                      c) LIFO                      d) LRU

**Q9.** Bubble sort is implemented using a technique that repeatedly compares adjacent pairs of elements from left to right and swaps them if they are in the wrong order. Which of the following is the total number of comparisons for sorting a list of “ $n$ ” elements?

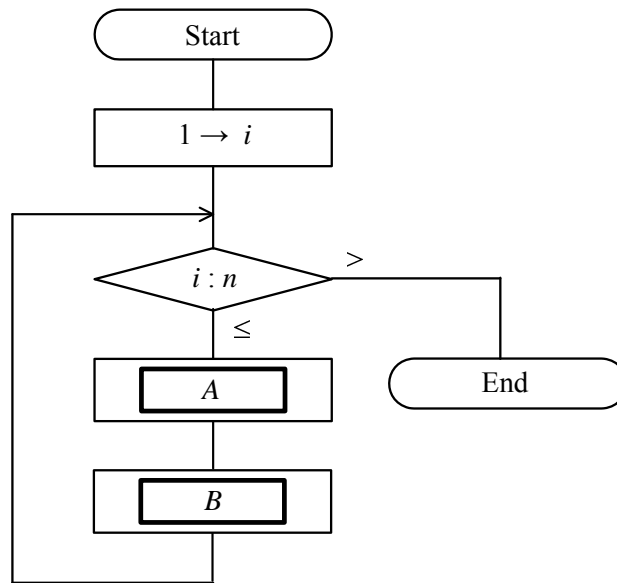
a)  $\frac{n}{2}$

b)  $\frac{n(n+1)}{2}$

c)  $\frac{n(n-1)}{2}$

d)  $\frac{n^2}{2}$

**Q10.** The flowchart below shows an algorithm that can be used to sort all elements of one-dimensional array  $X$  in reverse order and store them in array  $Y$ . In order to complete the algorithm, which of the following should be inserted into blanks  $A$  and  $B$ ? Here, the indices of the first and last elements of each array are 1 and  $n$  respectively.



	$A$	$B$
a)	$X(i-1) \rightarrow Y(n-i)$	$i+1 \rightarrow i$
b)	$X(i) \rightarrow Y(n-i+1)$	$i+1 \rightarrow i$
c)	$X(n-1) \rightarrow Y(i-n)$	$n+1 \rightarrow n$
d)	$X(n) \rightarrow Y(i-n+1)$	$n+1 \rightarrow n$

**Q8.** There are two one-dimensional arrays  $A$  and  $B$  of size  $m$  and  $n$  respectively. Each array contains unique integer values sorted in ascending order. As shown in a sample figure below, these two arrays are merged into a single one-dimensional array  $C$ . Which of the following is the appropriate order of the computational complexity of this merge algorithm?

$A$ : 

3	6	15	17
---	---	----	----

$B$ : 

7	9	11	18	20
---	---	----	----	----

$C$ : 

3	6	7	9	11	15	17	18	20
---	---	---	---	----	----	----	----	----

a)  $O(m)$

b)  $O(n)$

c)  $O(m + n)$

d)  $O(m \times n)$



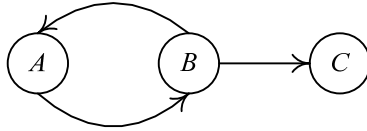
**Q9.** Which of the following is the expression that represents the result “ $x$ ” obtained by the series of three-address instructions below? Here, in a three-address instruction, an instruction using three operands “ $c = a \text{ op } b$ ” is represented as “ $\text{op } (a, b, c)$ ”. “ $\text{op}$ ” represents an operator. In the expression that represents the result “ $x$ ”, priority decreases in order of  $*$ ,  $/$ ,  $+$ , and  $-$ .

$/ (c, d, w1)$   
 $+ (b, w1, w2)$   
 $/ (e, f, w3)$   
 $- (w3, g, w4)$   
 $* (w2, w4, x)$

- a)  $b + c/d * e/f - g$   
 c)  $(b + c/d) * e/f - g$

- b)  $b + c/d * (e/f - g)$   
 d)  $(b + c/d) * (e/f - g)$

**Q5.** An adjacency matrix is used for representing which vertices of a directed or undirected graph are adjacent to which other vertices. Which of the following is the appropriate matrix that can represent the directed graph below?



a)

	<i>A</i>	<i>B</i>	<i>C</i>
<i>A</i>	1	1	1
<i>B</i>	1	1	1
<i>C</i>	0	0	1

b)

	<i>A</i>	<i>B</i>	<i>C</i>
<i>A</i>	1	0	1
<i>B</i>	0	1	0
<i>C</i>	1	1	1

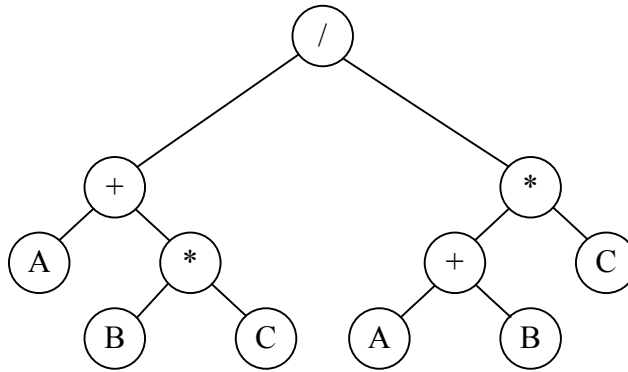
c)

	<i>A</i>	<i>B</i>	<i>C</i>
<i>A</i>	0	1	1
<i>B</i>	1	0	1
<i>C</i>	0	0	1

d)

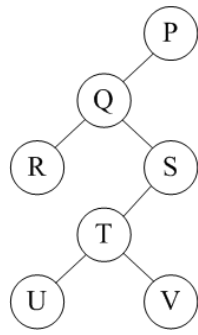
	<i>A</i>	<i>B</i>	<i>C</i>
<i>A</i>	0	1	0
<i>B</i>	1	0	1
<i>C</i>	0	0	0

- Q7.** An expression tree is a binary tree that is used to represent a mathematical expression and generate any of the three representations (infix, prefix, and postfix notations) by using one of the three traversals (in-order, pre-order, and post-order traversals) of the binary tree. Which of the following is one of the possible expressions generated by the expression tree shown below?



- |                                  |                                  |
|----------------------------------|----------------------------------|
| a) $(A * B + C) / ((A + B) * C)$ | b) $(A + B * C) / ((A + B) * C)$ |
| c) $(A + B / C) * ((A + B) * C)$ | d) $(A + B * C) / (A + B * C)$   |

- Q8.** When the binary tree shown in the figure below is stored in a one-dimensional array  $A[i]$  under the following conditions, what is the array index of the node “T”?

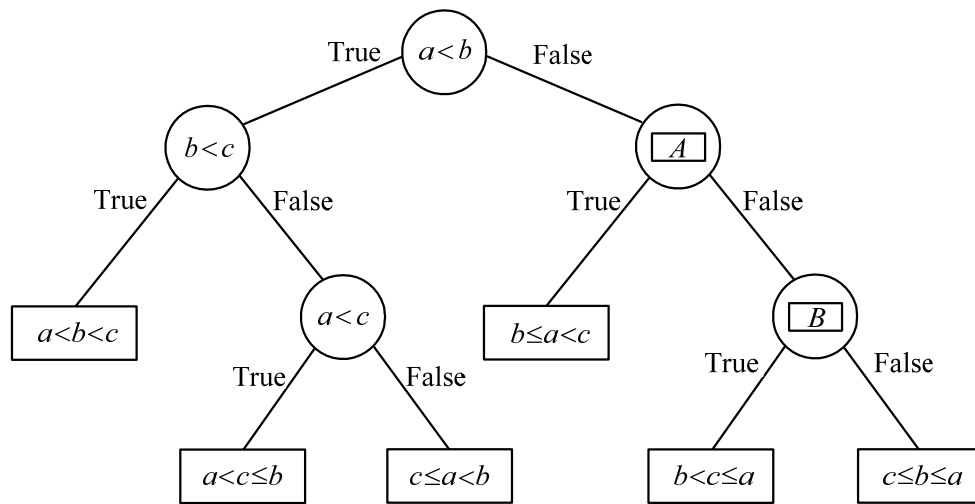


[Conditions]

- The root node is stored in  $A[1]$ .
- The left child of the node stored in index “ $i$ ” is in index “ $2i$ ”.
- The right child of the node stored in index “ $i$ ” is in index “ $2i+1$ ”.
- The parent of the node stored in index “ $i$ ” is stored in index “ $i/2$ ” (rounded down to the nearest integer).

- a) 3                      b) 6                      c) 7                      d) 10

**Q10.** When the decision tree shown below is used for sorting three numbers  $a$ ,  $b$ , and  $c$ , which of the following is the correct combination of expressions to be inserted in blanks  $A$  and  $B$ ?



	$A$	$B$
a)	$a < c$	$b < c$
b)	$a < c$	$c < a$
c)	$b < c$	$a < c$
d)	$c < a$	$b < c$

**Q3.** Which of the following prefix expressions is equivalent to the infix expression “ $(A+B)*C-(D-E)$ ”?

a)  $- * + A B C - D E$

b)  $- + A B * C - D E$

c)  $A B + C * - D E -$

d)  $A B + C * D E - -$

**Q4.** The syntax rules of the field identifier “field ID” are represented in BNF notation as shown below. When each ID is defined as an arbitrary sequence of letters and/or digits, which of the following should be inserted into the blank *A*?

$\langle \text{field ID} \rangle ::= \langle \text{ID} \rangle \mid \langle \text{field ID} \rangle . \langle \text{ID} \rangle$

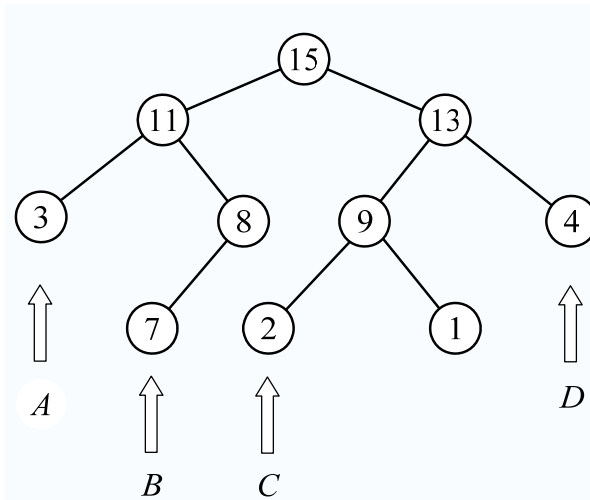
$\langle \text{ID} \rangle ::= \boxed{\text{A}}$

$\langle \text{letter} \rangle ::= \text{a} \mid \text{b} \mid \text{c} \mid \text{d} \mid \text{e} \mid \text{f} \mid \text{g} \mid \text{h} \mid \text{i} \mid \text{j} \mid \text{k} \mid \text{l} \mid \text{m} \mid \text{n} \mid \text{o} \mid \text{p} \mid \text{q} \mid \text{r} \mid \text{s} \mid \text{t} \mid \text{u} \mid \text{v} \mid \text{w} \mid \text{x} \mid \text{y} \mid \text{z}$

$\langle \text{digit} \rangle ::= 0 \mid 1 \mid 2 \mid 3 \mid 4 \mid 5 \mid 6 \mid 7 \mid 8 \mid 9$

- a)  $\langle \text{ID} \rangle . \langle \text{letter} \rangle \mid \langle \text{ID} \rangle . \langle \text{digit} \rangle$
- b)  $\langle \text{ID} \rangle \langle \text{letter} \rangle \mid \langle \text{ID} \rangle \langle \text{digit} \rangle \mid \langle \text{ID} \rangle . \langle \text{ID} \rangle$
- c)  $\langle \text{letter} \rangle \mid \langle \text{digit} \rangle \mid \langle \text{ID} \rangle \langle \text{letter} \rangle \mid \langle \text{ID} \rangle \langle \text{digit} \rangle$
- d)  $\langle \text{letter} \rangle \langle \text{ID} \rangle \mid \langle \text{digit} \rangle \langle \text{ID} \rangle$

- Q5.** As shown in the figure below, there is a binary tree which is created in accordance with a specific rule that the value of a parent node is greater than that of a child element.



When a new element with the value 12 is inserted in the places marked by *A*, *B*, *C*, or *D* in the tree according to the steps defined below, where should it be inserted in order to maintain the specific rule and minimize the number of exchanges?

[Steps]

1. Add the element to a leaf node of the tree.
2. Compare the added element with its parent; if the result is in the correct order, stop. If not, go to Step 3.
3. Exchange the element for its parent and return to Step 2.

a) *A*

b) *B*

c) *C*

d) *D*



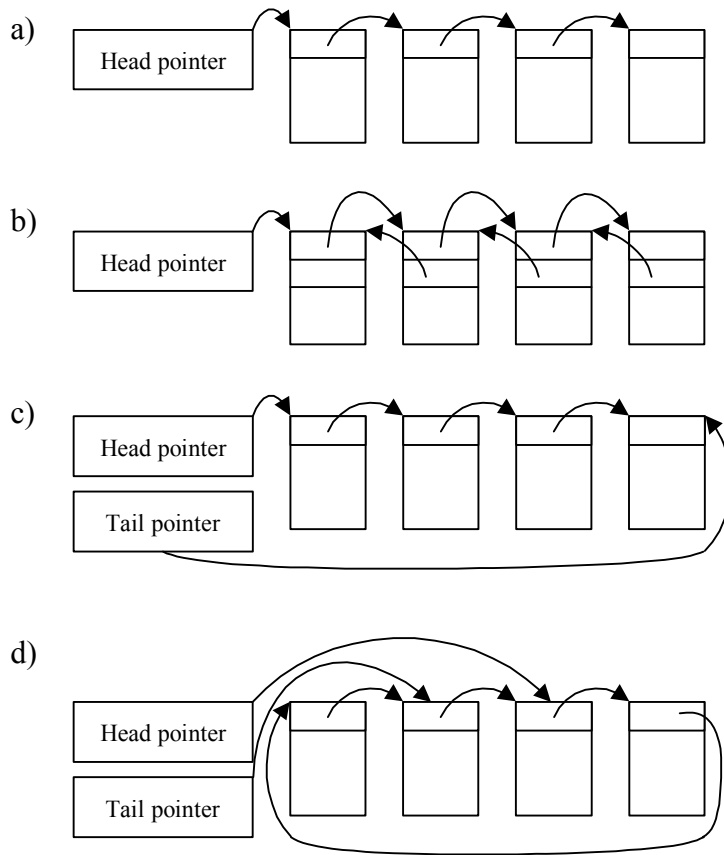
- Q6.** Tic-tac-toe, also known as noughts and crosses, is a popular game for two players, O and X, who take turns marking the spaces in a  $3 \times 3$  grid. The player who succeeds in placing three respective marks in a horizontal, vertical, or diagonal row wins the game. For example, the player O wins on the tic-tac-toe board shown below.

O	X	X
X	O	O
X	O	O

How many possible combinations of moves are there to fill all of the nine spaces, regardless of wins and losses?

- a)  $2^9$                       b)  $^9 - 1$                       c)  $9!$                       d)  $9! - 1$

**Q8.** When a linked list is used for queue implementation, which of the following structures provides the most efficient and effective way to perform both “insert” and “delete” operations? Here, the number of queue elements is variable, and the arrows shown in the figures represent link pointers.



**Q9.** Which of the following is an appropriate description concerning a binary search tree whose node values are 17, 6, 19, 3, 22, and 32?

- a) Any binary tree containing these values has a maximum depth of three (3).
- b) No matter which value is placed at the root node, “3” cannot have a left child.
- c) No matter which value is placed at the root node, “3” is always at the deepest level.
- d) The root node value cannot be “32”.

**Q10.** In a binary tree,

- any node that has two null children is called a leaf node, and
- the other nodes except leaf nodes have one or two non-null children.

When the number of nodes including leaf nodes is  $n$ , how many null children are included in the binary tree?

a)  $2n$

b)  $n$

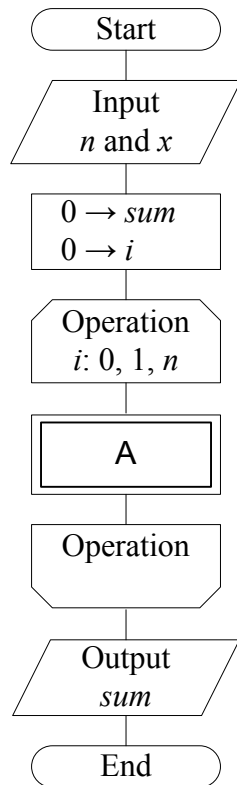
c)  $n-1$

d)  $n+1$

**Q11.** Which of the following data structures can be referred to as a “last-in first-out” operation?

- a) Binary tree      b) List      c) Queue      d) Stack

**Q13.** When the expression  $1 - \frac{1}{x} + \frac{1}{x^2} - \frac{1}{x^3} + \frac{1}{x^4} - \dots \frac{1}{x^n}$  is calculated, which of the following should be inserted in the process box A in the flowchart shown below?



At the start of the loop, repetition conditions indicate “variable name: initial value, increment, final value.”

- a)  $sum + ((-1)^i \times x^i) \rightarrow sum$   
 c)  $sum + ((-1)^{i+1} \times x^i) \rightarrow sum$

- b)  $sum + ((-1)^i \times x^{-i}) \rightarrow sum$   
 d)  $sum + ((-1)^{i+1} \times x^{-i}) \rightarrow sum$

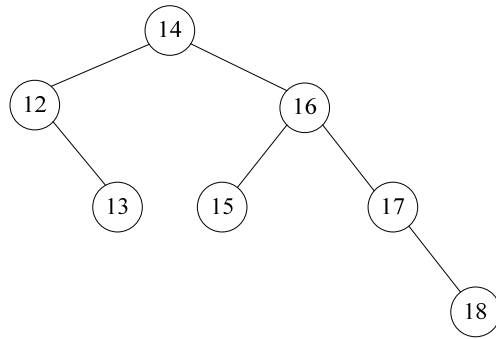
**Q4.** The function  $f(x)$  has a real-type argument and a real-type return value. The procedure using this function is shown in the steps 1 through 5. When this procedure is executed repeatedly a sufficient number of times and the value of  $y$  stops changing in the step 3, which of the following expressions holds?

[Steps]

1.  $x \leftarrow a$
2.  $y \leftarrow f(x)$
3. Display the value of  $y$
4.  $x \leftarrow y$
5. Return to the step 2

- a)  $f(a) = y$       b)  $f(y) = 0$       c)  $f(y) = a$       d)  $f(y) = y$

**Q12.** Which of the following terms is applicable to the binary tree shown below?



- a) AVL tree
- b) Full binary tree
- c) Max heap
- d) Perfect binary tree

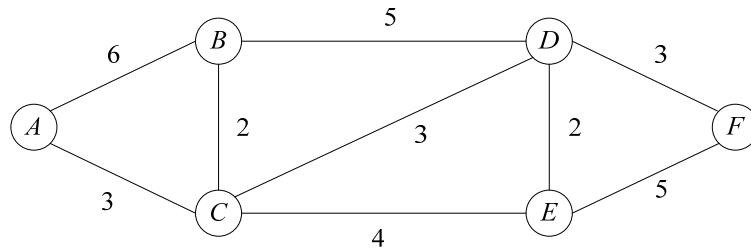


**Q13.** In a unidirectional list shown below, *Blue* is the top of the list, and its pointer indicates the next data address 110. In addition, *Yellow* is the end of the list, and its pointer is 0. Which of the following operations can replace *Green* with *Red* in the list?

Pointer to top of list	Address	Data	Pointer
120	100	<i>Pink</i>	130
	110	<i>Green</i>	100
	120	<i>Blue</i>	110
	130	<i>Yellow</i>	0
	140	<i>Red</i>	

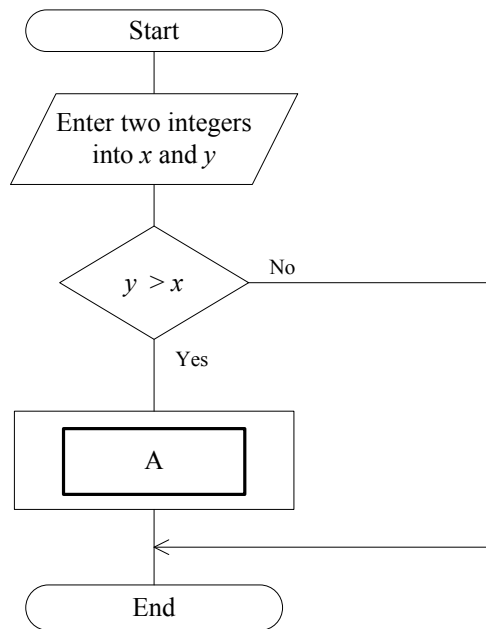
- a) Set the pointers of *Red* and *Blue* to 100 and 140 respectively.
- b) Set the pointers of *Red* and *Blue* to 110 and 140 respectively.
- c) Set the pointers of *Red* and *Green* to 100 and 140 respectively.
- d) Set the pointers of *Red* and *Green* to 110 and 140 respectively.

**Q14.** In the graph shown below, which of the following is an appropriate description concerning the shortest path from the node “A” to another node? Here, the number shown beside the line indicates the distance between the two adjacent nodes.



- a) The shortest distance from  $A$  to  $B$  is 6.
- b) The shortest distance from  $A$  to  $D$  is 10.
- c) The shortest distance from  $A$  to  $E$  is 13.
- d) The shortest distance from  $A$  to  $F$  is 9.

**Q16.** The flowchart below shows an algorithm in which two integers are temporarily entered into two variables  $x$  and  $y$  at the beginning, and then, after comparison of the two integers, the larger number is stored in the variable  $x$  and the smaller is in the variable  $y$ . In order to complete the algorithm, which of the following should be inserted in the process box **A** in the flowchart?



- |                      |                          |                          |                      |
|----------------------|--------------------------|--------------------------|----------------------|
| a) $x \rightarrow t$ | b) $x + y \rightarrow x$ | c) $x + y \rightarrow x$ | d) $y \rightarrow x$ |
| $t \rightarrow y$    | $x - y \rightarrow x$    | $x - y \rightarrow y$    | $x \rightarrow y$    |
| $y \rightarrow x$    | $x - y \rightarrow y$    | $x - y \rightarrow x$    |                      |

**Q12.** Which of the following is the minimum possible depth of a binary tree with 14 nodes?

a) 0

b) 3

c) 4

d) 5

**Q13.** Which of the following appropriately describes a characteristic of linked lists?

- a) It is not used for a homogeneous collection of elements.
- b) The elements are always stored in a physically contiguous area.
- c) The elements can be stored only in a dynamic way, not in a static way.
- d) The elements cannot be accessed directly or randomly.

**Q14.** There is a two-dimensional array  $A(m, n)$  with  $m$  rows and  $n$  columns, and the array in physically contiguous memory addresses is accessed such that rows are stored one after another, in row-major order. Which of the following is the correct memory address of any given element  $A(i, j)$ ? Here, both  $m$  and  $n$  are greater than 0, and the indices  $i$  and  $j$  range from 1 to  $m$  and  $n$  respectively. In addition,  $x$  is the memory address of the element  $A(1, 1)$ .

- |                                     |                                     |
|-------------------------------------|-------------------------------------|
| a) $x + n \times i + j$             | b) $x + n \times (i + 1) + (j + 1)$ |
| c) $x + n \times (i - 1) + (j - 1)$ | d) $x + n \times (j - 1) + (i - 1)$ |

**Q16.** When a program (or a function) calls itself recursively, which of the following data structures is suitable for storing the data that is currently used in the program?

- a) Array                      b) Linked list                      c) Stack                      d) Tree

**Q5.** There are a total of  $N$  values observed. The sum  $S$  ( $S > 0$ ) of these values is obtained, and then the average value is calculated. Which of the following is the correct expression when the average value is rounded off to the nearest integer value? Here, “/” indicates division, and  $[X]$  is the maximum integer equal to  $X$  or less.

a)  $[(S+0.5)/N]$

b)  $[(S-1)/N]+1$

c)  $[S/N+0.5]$

d)  $[S/N]+1$



- Q6.** A  $k$ -string is a character string with a length of  $k$  characters. An  $m$ -substring is an ordered sequence with a length of  $m$  characters, which consists of consecutive elements of the original  $k$ -string. An  $n$ -subsequence is also an ordered sequence with a length of  $n$  characters, which consists of elements of the original  $k$ -string, but it does not need to be consecutive. How many  $m$ -substrings and  $n$ -subsequences are respectively included in the  $k$ -string?

	Total number of $m$ -substrings	Total number of $n$ -subsequences
a)	$k - m + 1$	$\frac{k!}{n!(k-n)!}$
b)	$k - m$	$\frac{k!}{n!(k-n)!}$
c)	$k - m + 1$	$\frac{k!}{(k-n)!}$
d)	$k - m$	$\frac{k!}{(k-n)!}$

**Q13.** A  $k$ -ary tree is a tree in which every node has no more than  $k$  children. A binary tree is the special case where  $k=2$ . In a  $k$ -ary tree with  $n$  nodes and height  $h$ , which of the following is an upper bound for the number of leaves?

a)  $h^k$

b)  $k^h$

c)  $\log_k n$

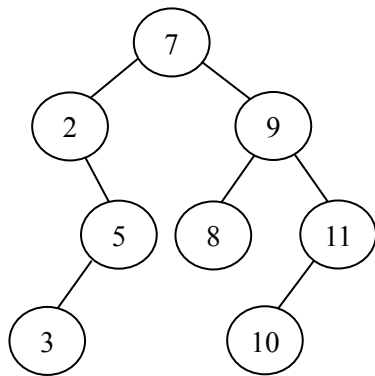
d)  $n/\log_k h$

**Q15.** A binary search tree is created by inserting the values shown below.

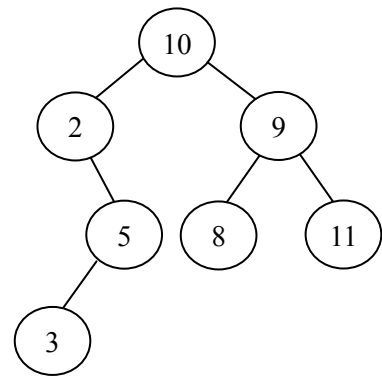
7 9 11 2 8 10 5 3

After deletion of the root from the newly created tree, what does it look like?

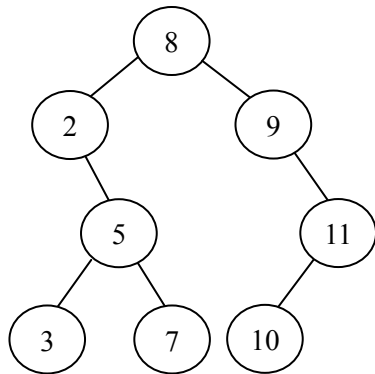
a)



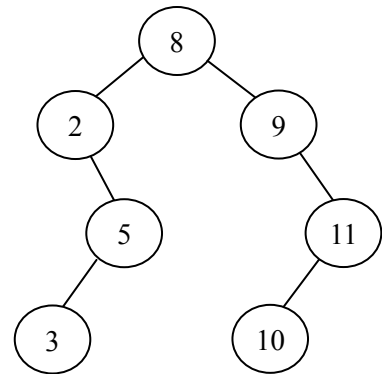
b)



c)



d)



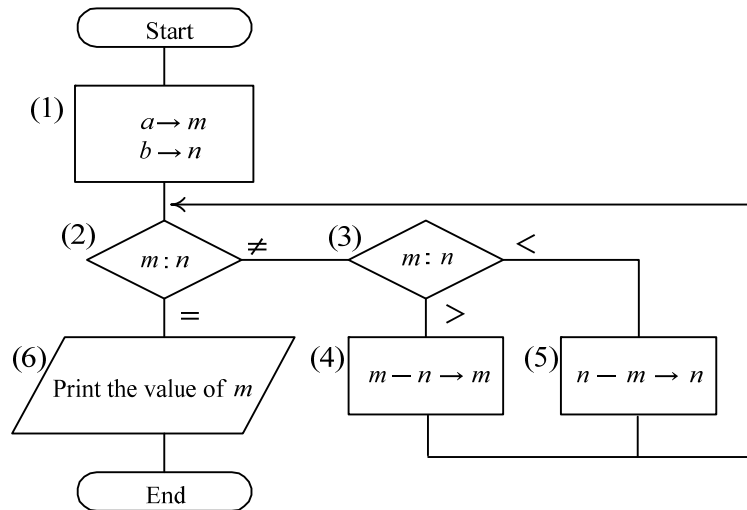
**Q16.** Which of the following is the sorting algorithm that divides the data elements into two groups, in which all those elements less than a particular element (called a pivot value) and all those elements greater than or equal to it are separately included, and then repeats the same operation until all elements are sorted in ascending or descending order?

- a) Heap sort
- b) Insertion sort
- c) Merge sort
- d) Quick sort

**Q42.** In the flowchart below, which of the following indicates the relationship between the initial values  $a$  and  $b$  that are given in  $m$  and  $n$  in the process (1) in order to carry out these processes in the order shown below?

(1)  $\rightarrow$  (2)  $\rightarrow$  (3)  $\rightarrow$  (5)  $\rightarrow$  (2)  $\rightarrow$  (3)  $\rightarrow$  (4)  $\rightarrow$  (2)  $\rightarrow$  (6)

Here,  $a$  and  $b$  are both positive integers.



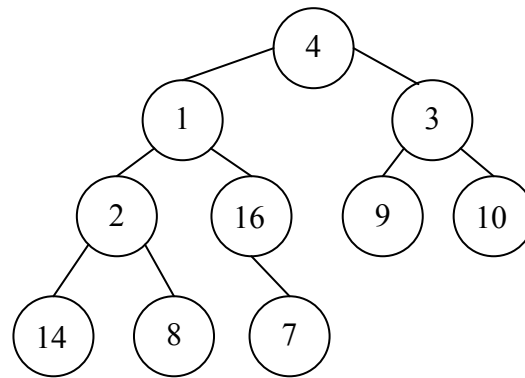
a)  $a = 2b$

b)  $2a = b$

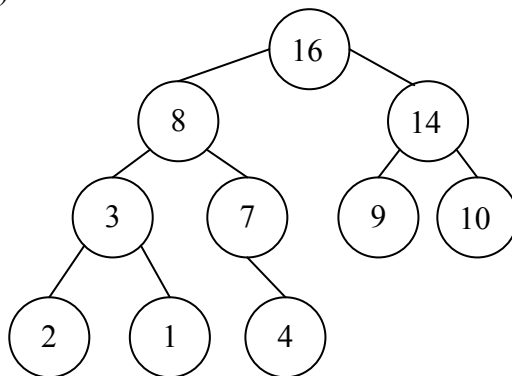
c)  $2a = 3b$

d)  $3a = 2b$

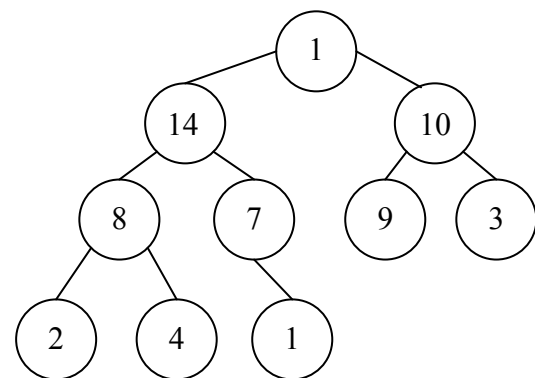
**Q12.** In the binary tree shown below, which of the following trees is created after conversion into a (max) heap?



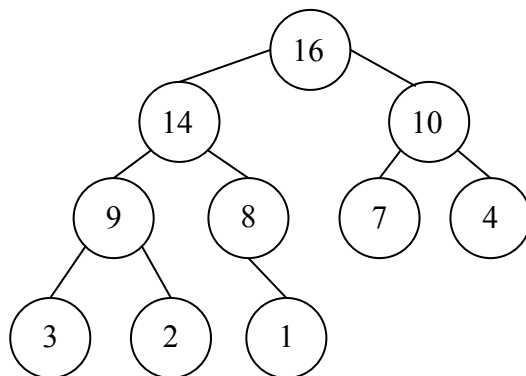
a)



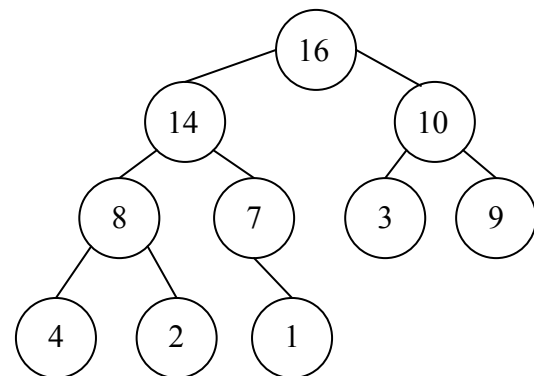
b)



c)



d)

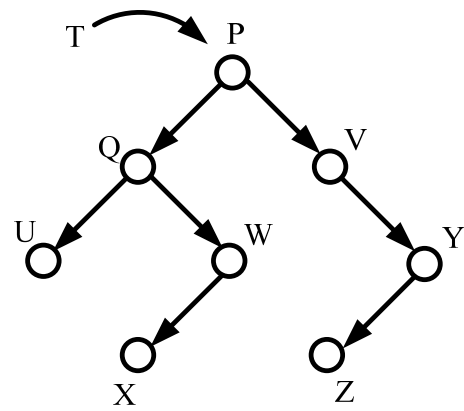


**Q13.** A singly linked list is implemented using two arrays `VALUE` and `LINK`, in which `LINK(I)` points to the successor of `VALUE(I)`. When a new element that does not exist initially in the list is assigned to `VALUE(J)`, the program fragment shown below is executed. Which of the following appropriately describes the function of this program?

```
LINK(J) <- LINK(I);  
LINK(I) <- J;
```

- a) `VALUE(I)` is replaced by `VALUE(J)` in the list.
- b) `VALUE(J)` is inserted after `VALUE(I)` in the list.
- c) `VALUE(J)` is inserted before `VALUE(I)` in the list.
- d) `VALUE(J)` is replaced by `VALUE(I)` in the list.

**Q15.** Which of the following represents the sequence of nodes visited in a post-order traversal of the binary tree T shown below?

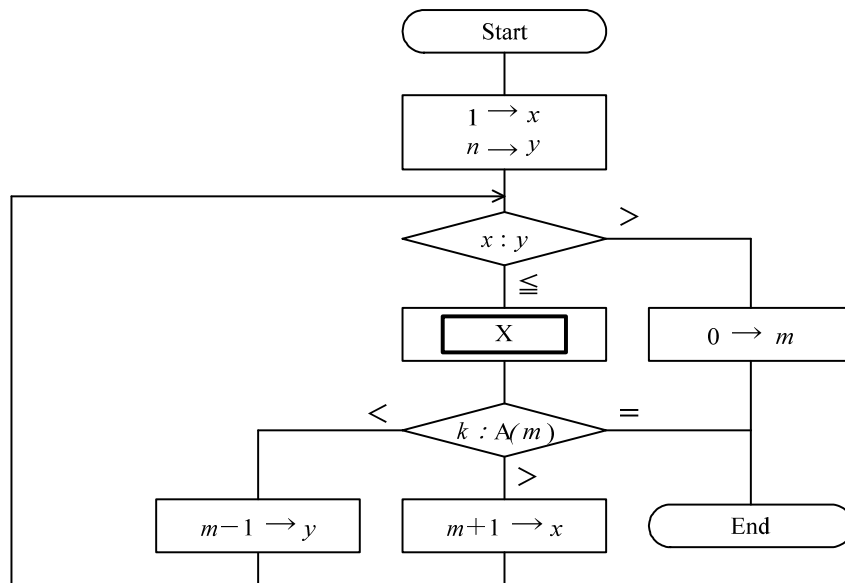


- a) U Q X W P V Z Y
- c) U X Z Q W Y V P

- b) U X W Q Z Y V P
- d) X Z U W Y Q V P



**Q16.** The flowchart below shows a binary search algorithm to find the index  $m$  of the array element  $A(m)$ , such that the equation “ $A(m) = k$ ” holds, from the array elements  $A(1)$ ,  $A(2)$ , ...,  $A(n)$  already sorted in ascending order. In case of “ $m = 0$ ” at the end, there is no element such that the equation “ $A(m) = k$ ” holds. Which of the following is inserted in the process box  $\boxed{X}$  in the flowchart? Here, the slash ( / ) indicates division that truncates all digits after the decimal point.

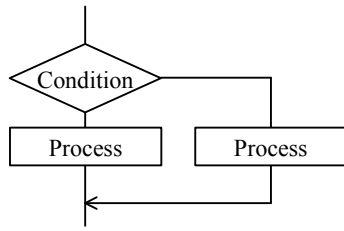


- a)  $(x + y) \quad m$   
 c)  $(x - y) / 2 \quad m$

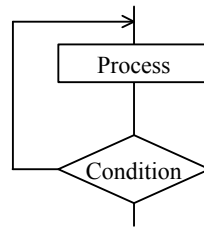
- b)  $(x + y) / 2 \quad m$   
 d)  $(y - x) / 2 \quad m$

**Q36.** Which of the following flowcharts illustrates a “while repetition structure” in the control structure of programs?

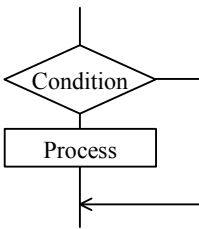
a)



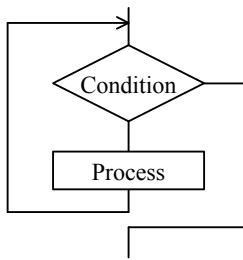
b)



c)



d)



- Q6.** Which of the following is the appropriate statement concerning Newton's method that is known as an algorithm for obtaining the approximate value of the solution to the formula  $f(x) = 0$ ?
- a) An approximate value of the solution can be obtained even if the function  $f(x)$  is indifferentiable.
  - b) An approximate value of the solution is obtained geometrically using the tangent lines of  $y = f(x)$ .
  - c) No matter what initial values are provided, an approximate value of the solution can always be obtained.
  - d) Two different initial values must be provided.

**Q12.** Which of the following data structures uses the LIFO (Last In First Out) method in order to manage data?

- a) Array                      b) Linked list                      c) Queue                      d) Stack

**Q13.** In a microprocessor, there are two general registers: GRi and GRj (hereinafter referred to as GRx instead of GRi or GRj). PUSH GRx is used for adding the contents of GRx to the top of a stack. POP GRx is for removing the current top data of the stack and storing it to GRx. Which of the following operations can exchange the contents of GRi and GRj?

- a) PUSH GRi  
POP GRj  
PUSH GRj  
POP GRi
- b) PUSH GRj  
POP GRi  
PUSH GRi  
POP GRj
- c) PUSH GRi  
PUSH GRj  
POP GRi  
POP GRj
- d) PUSH GRi  
PUSH GRj  
POP GRj  
POP GRi

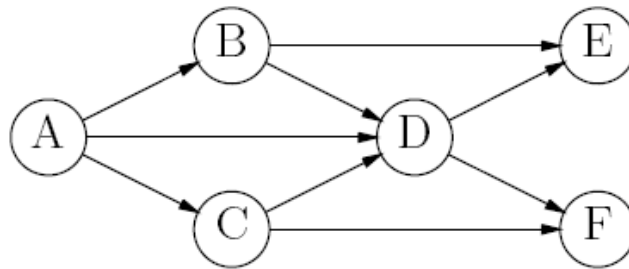
**Q14.** Which of the following is the appropriate statement concerning data sorting methods?

- a) The “bubble sort” method determines an intermediate reference value and divides the elements into two groups of “larger” values and “smaller” values. This operation is then repeated recursively on these two groups.
- b) The “heap sort” method builds an ordered tree from the unsorted portion of the elements, extracts the maximum or minimum value from this ordered tree, and moves it to the sorted portion. This operational sequence is then repeated to gradually shrink the unsorted portion.
- c) The “quick sort” method sorts each substring composed of elements extracted at regular intervals, and then the interval is further decreased and the same operation is performed again. This operation is repeated until the interval becomes 1.
- d) The “shell sort” method repeatedly compares two adjacent elements and swaps them if the first element is larger than the second.

**Q15.** A binary tree is said to be perfect, if all its leaves are at the same depth and every internal node has two children. Which of the following is correct about the perfect binary tree? Here,  $n$  is the number of nodes, and  $h$  is the height of the perfect binary tree.

- a)  $h = \log_2(n+1)$
- b) If every proper subtree of a binary tree is perfect, then the tree itself must also be perfect.
- c)  $n = 2^{h+1} - 1$
- d) The number of internal nodes is  $2^h$ .

**Q16.** A depth-first search (DFS) visits all the vertices in a graph. When an edge to be explored next is chosen, this algorithm always chooses to go “deeper” into the graph. That is, it will pick the next adjacent unvisited vertex until reaching a vertex that has no unvisited adjacent vertices. The algorithm will then backtrack to the previous vertex and continue along any as-yet unexplored edges from that vertex. After DFS has visited all the reachable vertices from a particular source vertex, it chooses one of the remaining undiscovered vertices and continues the search. Which of the following is not a valid order in which the vertices of the graph below can be marked as “visited” during a DFS?



- |           |           |
|-----------|-----------|
| a) ABCDEF | b) ABDFEC |
| c) ABEDFC | d) ADEFCB |



**Q9.** Reverse Polish Notation (RPN) is used to represent arithmetic expressions without using brackets to define priorities for evaluation of operators. For example,  $3 \times (a+b)$  becomes  $3ab+\times$  in RPN. Which of the following is the best data structure that should be used for implementation of RPN in a computer?

- a) List                      b) Queue                      c) Stack                      d) Tree

**Q10.** Which of the following is an appropriate description concerning the list and/or array structures?

- a) The list structure allows any data to be inserted or deleted simply by modifying pointers. But, after the data was deleted, the cells that contained the data remain as garbage in memory.
- b) The list structure is similar to the array structure in that all data elements of the same type are sequentially lined up. In the list structure, the logical arrangement is the same as the physical arrangement.
- c) The number of operations is fixed in inserting or deleting an element in an array; it does not depend on the position of the element in the array.
- d) Using a subscript for each element in an array, quick access to any element can be achieved. The array structure allows any data to be inserted or deleted simply by modifying pointers.

**Q11.** The table below shows a state transition table that checks the input character string. This check starts from the initial state *A*, and it fails if the state changes to *E* during the input of the character string. Which of the character strings in the answer group fails this check? Here, the symbol  $\Delta$  in the answer group represents a space.

		Input character				
		Space	meric	Sign	Radix point	Other
Current state	<i>A</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>
	<i>B</i>	<i>A</i>	<i>B</i>	<i>E</i>	<i>D</i>	<i>E</i>
	<i>C</i>	<i>E</i>	<i>B</i>	<i>E</i>	<i>D</i>	<i>E</i>
	<i>D</i>	<i>A</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>

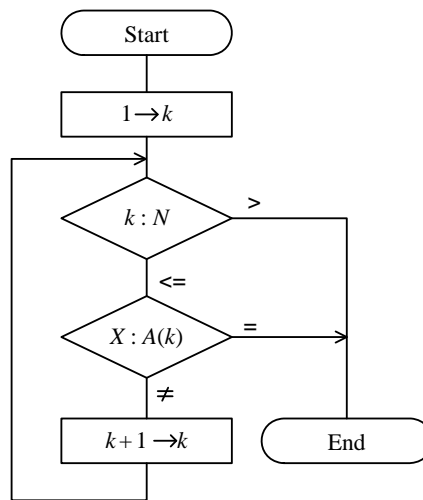
a) +0010

b) -1

c) 12.2

d) 9. $\Delta$

- Q16.** Integers are stored in the 1st to  $N$ -th elements of an array  $A$  ( $N > 1$ ). The flowchart below shows the process to check which element of the array contains the same value as  $X$ . Which of the following correctly describes the execution result of this process?



- a) If the same value as  $X$  exists in two places of the array, the 1st and  $N$ -th elements,  $k$  is set to 1.
- b) If the same value as  $X$  exists in two places of the array, the 1st and  $N$ -th elements,  $k$  is set to  $N$ .
- c) If the same value as  $X$  is not in the array,  $k$  is set to 1.
- d) If the same value as  $X$  is not in the array,  $k$  is set to  $N$ .

**Q4.** Which of the following is an expression in reverse Polish notation that has the same value as the expression below when evaluated? Here, numbers are given as decimals, and the symbols  $-$  and  $\times$  are subtraction and multiplication operators, respectively.

$$3 \ 4 \ - \ 5 \ \times$$

a)  $3 \ 4 \ 5 \ \times \ -$

b)  $4 \ 5 \ - \ 3 \ \times$

c)  $5 \ 3 \ 4 \ - \ \times$

d)  $5 \ 4 \ 3 \ - \ \times$

**Q5.** The table below shows state transition for character string inspection. During the inspection, if the state changes to *E*, the string under inspection is rejected. Which of the following is rejected in this inspection? Here, state *A* is the initial state, strings are inspected from left to right, and symbol  $\Delta$  indicates a blank character.

		Character				
		Blank	Number	Sign	Radix point	Other
Current state	<i>A</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>
	<i>B</i>	<i>A</i>	<i>B</i>	<i>E</i>	<i>D</i>	<i>E</i>
	<i>C</i>	<i>E</i>	<i>B</i>	<i>E</i>	<i>D</i>	<i>E</i>
	<i>D</i>	<i>A</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>

a) +0010

b) -1

c) 12.2

d) 9. $\Delta$

**Q7.** For two-dimensional integer array  $A$ , whose  $(i, j)$ -th element  $A[i, j]$  is  $2 \times i + j$ , what is the value of element  $A[A[1, 1] \times 2, A[2, 2] + 1]$ ?

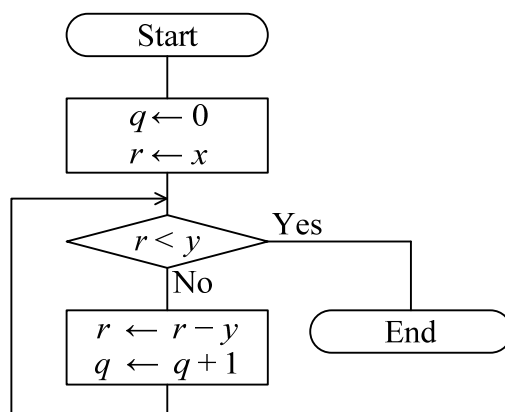
a) 12

b) 13

c) 18

d) 19

**Q8.** For two non-negative integers  $x$  and  $y$ , which of the following is the result of the procedure shown in the flowchart below?



	Value of $q$	Value of $r$
a)	Quotient of $x \div y$	Remainder of $x \div y$
b)	Quotient of $y \div x$	Remainder of $y \div x$
c)	Remainder of $x \div y$	Quotient of $x \div y$
d)	Remainder of $y \div x$	Quotient of $y \div x$



**Q10.** When the Bubble sort algorithm is used, how many exchange operations are required to sort the numbers in ascending order?

9, 2, 13, 21, 3, 0

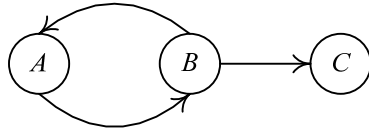
a) 7

b) 8

c) 9

d) 10

**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)

	<i>A</i>	<i>B</i>	<i>C</i>
<i>A</i>	1	1	1
<i>B</i>	1	1	1
<i>C</i>	0	0	1

b)

	<i>A</i>	<i>B</i>	<i>C</i>
<i>A</i>	1	0	1
<i>B</i>	0	1	0
<i>C</i>	1	1	1

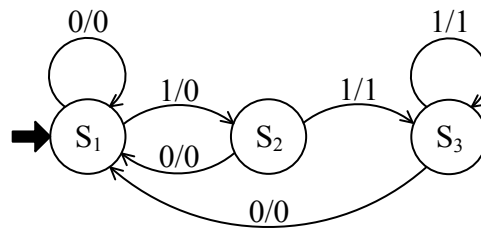
c)

	<i>A</i>	<i>B</i>	<i>C</i>
<i>A</i>	0	1	
<i>B</i>	1	0	
<i>C</i>	0	0	

d)

	<i>A</i>	<i>B</i>	<i>C</i>
<i>A</i>	0	1	0
<i>B</i>	1	0	1
<i>C</i>	0	0	0

**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
- c) 0010001000

- b) 0001001110
- d) 0011111110

**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())

$y \leftarrow \text{pop}()$

a) 1

b) 2

c) 3

d) 4

**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

**Q3.** The GCD (Greatest Common Divisor) of two positive integers,  $x_0$  and  $x_1$  ( $x_0 > x_1$ ), is computed by the procedure below. When  $x_0 = 175$  and  $x_1 = 77$ , how many times should step (2) of this procedure be executed before it stops? Here, " $A \leftarrow B$ " indicates that  $B$  is substituted for  $A$ .

[Procedure]

- (1)  $i \leftarrow 2$
- (2)  $x_i \leftarrow$  remainder of  $x_{i-2}$  divided by  $x_{i-1}$
- (3) if  $x_i = 0$ , stop with  $x_{i-1}$  as the GCD
- (4)  $i \leftarrow i + 1$
- (5) return to step (2)

a) 3

b) 4

c) 6

d) 7

**Q5.** The table below is a state transition table used for character string validation. In this table, “*A*” represents the initial state, and “*E*” represents the failure state. Which of the following is a character string that fails this validation? Here, each character of a string is parsed from the leftmost side, and the symbol “ $\Delta$ ” represents a blank character.

		Character				
		Blank	Nu	Sign	Radix point	Other
Current state	<i>A</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>	<i>E</i>
	<i>B</i>	<i>A</i>	<i>B</i>	<i>E</i>	<i>D</i>	<i>E</i>
	<i>C</i>	<i>E</i>	<i>B</i>	<i>E</i>	<i>D</i>	<i>E</i>
	<i>D</i>	<i>A</i>	<i>E</i>	<i>E</i>	<i>E</i>	<i>E</i>

a) +0010

b) −1

c) 12.2

d) 9. $\Delta$

**Q7.** When a sequence of data,  $A, B, C, D$ , arrives in this order, which of the following is a possible sequence that can be produced using a single stack?

a)  $A, D, B, C$

b)  $B, D, A, C$

c)  $C, B, D, A$

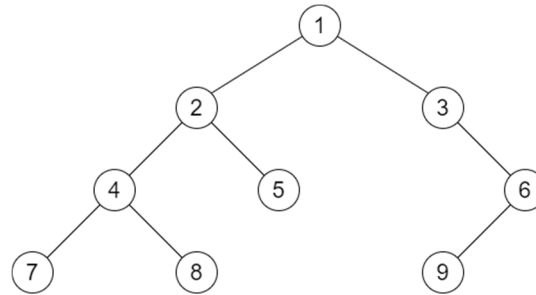
d)  $D, C, A, B$



**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?

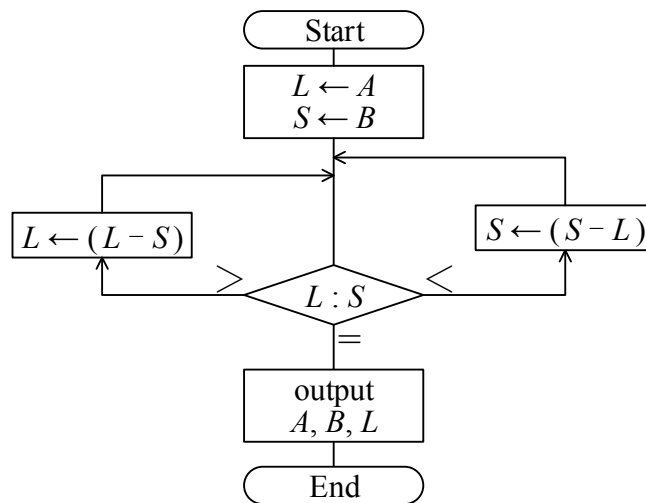


- |                              |                              |
|------------------------------|------------------------------|
| a) 1, 2, 4, 7, 8, 5, 3, 6, 9 | b) 6, 9, 3, 1, 5, 2, 8, 4, 7 |
| c) 7, 4, 8, 2, 5, 1, 3, 9, 6 | d) 7, 8, 4, 5, 2, 9, 6, 3, 1 |

**Q7.** Which of the following is a description of quicksort algorithm?

- a) It repeats the process of comparing and swapping each pair of adjacent elements so that smaller elements are gradually moved towards the end.
- b) It repeats the process of finding the minimum element of the data, followed by its removal.
- c) It repeats the process of inserting each element of data into the correct position of a sorted sequence.
- d) It repeats the process of selecting an element as a pivot and partitions the data so that smaller elements appear before the pivot, and larger elements appear afterwards.

**Q8.** The flowchart below calculates the greatest common divisor of two (2) numbers,  $A$  and  $B$ , using the Euclidean algorithm with repeated subtraction. When  $A$  is 876 and  $B$  is 204, how many comparisons are required to obtain the result?



- a) 4                      b) 9                      c) 10                      d) 11

**Q9.** There are three stacks,  $A$ ,  $B$ , and  $C$ , each having an initial state  $[1, 2, 3]$ , respectively. When the recursively defined function,  $f()$ , below, is called and terminates, what is the state of stack  $B$ ? Here,  $[a_0, a_1, \dots, a_{n-1}]$  represent the state of a stack. When  $a_n$  is **pushed** into this stack, the state becomes  $[a_0, a_1, \dots, a_{n-1}, a_n]$ .

```

f() {
    if  $A$  is empty {
        do nothing
    } else {
        pop a value from  $A$ , then push it into  $C$ 
        call  $f()$ 
        pop a value from  $C$ , then push it into  $B$ 
    }
}

```

- |                         |                         |
|-------------------------|-------------------------|
| a) $[1, 2, 3, 1, 2, 3]$ | b) $[1, 2, 3, 3, 2, 1]$ |
| c) $[3, 2, 1, 1, 2, 3]$ | d) $[3, 2, 1, 3, 2, 1]$ |

**Q5.** A list is implemented with two arrays `box` and `next`. Each element in the list corresponds to a pair  $(\text{box}[i], \text{next}[i])$ , where  $\text{box}[i]$  is the value of the element, and  $\text{next}[i]$  is the index to the next element in the list. When the element of value "H" is inserted between the third and fourth elements in the list shown below, which of the following is the value contained in  $\text{next}[8]$ ? Here,  $\text{next}[0]$  contains the index of the leading (first) element of the list, the index  $i$  whose  $\text{next}[i]$  is 0 indicates the last element of the list, and each index  $i$  whose  $\text{next}[i]$  is blank indicates that the element is out of the list.

	0	1	2	3	4	5	6	7	8	9
box		A	B	C	D	E	F	G	H	I
	0	1	2	3	4	5	6	7	8	9
next	1	5	0	7		3		2		

a) 3

b) 5

c) 7

d) 8

**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

**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

**Q5.** What is the result after evaluation of the following postfix expression? Here, symbols +, −, ×, and ÷ represent the arithmetic operators of addition, subtraction, multiplication, and division, respectively.

$$5\ 4\ 6\ +\ \times\ 4\ 9\ 3\ \div\ +\ \times$$

a) 98

b) 154

c) 238

d) 350



**Q6.** Two stack operations are defined:

PUSH  $n$ : Pushes a data (integer value  $n$ ) to the stack.

POP: Pops a data from the stack.

For an empty stack, which of the following is the result of performing stack operations in the sequence below?

PUSH 1 → PUSH 5 → POP → PUSH 7 → PUSH 6 →  
PUSH 4 → POP → POP → PUSH 3

a)

1
7
3

b)

3
4
6

c)

3
7
1

d)

6
4
3

**Q8.** The binary search algorithm is used to search for a given item when items are sorted. If the number of items is 1 million, which of the following is the closest to the maximum number of comparisons required to find the item?

a)

b) 2

c)

d) 3

**Q2.** How many four-digit decimal numbers are made from four (4) different digits between 0 and 9? Here, a four-digit decimal number has a non-zero leading digit.

a) 4320

b) 4436

c) 4536

d) 5040

**Q3.** What is the value of the postfix expression below when variables  $A$ ,  $B$ ,  $C$ , and  $D$  have values 4, 3, 5, and 6, respectively? Here, symbols '+', '-', '×', and '÷' represent the arithmetic operators of addition, subtraction, multiplication, and division, respectively.

$$A \ B \ 2 \ \times \ + \ D \ B \ \div \ C \ \times \ -$$

a) -3

b) 0

c) 3

d) 40/3

**Q6.** When the procedure described below is executed in sequence for an empty stack and empty queue, what is the value assigned to variable  $x$ ? Here, the functions used in the procedure are defined as follows:

[Function definitions]

push( $y$ ): pushes data  $y$  onto the top of the stack.

pop(): removes the data from the top of the stack and returns it as the function value.

enq( $y$ ): inserts data  $y$  at the tail of the queue.

deq(): removes the data from the head of the queue and returns it as the function value.

[Procedure]

push( $a$ )

push( $b$ )

enq(pop())

enq( $c$ )

push( $d$ )

push(deq())

$x \leftarrow \text{pop}()$

a)  $a$

b)  $b$

c)  $c$

d)  $d$

**Q7.** For a function  $f(x, y)$  defined below, what is the value of  $f(775, 527)$ ? Here,  $x \bmod y$  represents the remainder after division of  $x$  by  $y$ .

$f(x, y)$ : if  $y = 0$  then return  $x$  else return  $f(y, x \bmod y)$

- a) 0                      b) 31                      c) 248                      d) 527

**Q6.** There is a two-dimensional integer array A whose  $(i, j)$ -th element  $A[i, j]$  is  $2 \times i + j$ . What is the value of the element  $A[A[1, 1] \times 2, A[2, 2] + 1]$ ?

a) 12

b) 13

c) 18

d) 19

**Q7.** Function  $F(n)$  is a recursively defined integer function that calculates the factorial of  $n$  for any non-negative integer  $n$ . Which of the following is an appropriate expression for the blank A?

$$F(0) = 1$$

$$F(n) = \boxed{A} \text{ (if } n > 0\text{)}$$

a)  $n + F(n - 1)$

b)  $n - 1 + F(n)$

c)  $n \times F(n - 1)$

d)  $(n - 1) \times F(n)$



**Q3.** Which of the following expressions in postfix notation is equivalent to an expression  $2+5\times 3+4$  in infix notation? Here, the operator ' $\times$ ' has higher precedence than '+'.

a)  $2\ 5\ 3\ 4\ \times\ +\ +$

b)  $2\ 5\ +\ 3\ 4\ \times\ +$

c)  $2\ 5\ 3\ \times\ 4\ +\ +$

d)  $2\ 5\ 3\ \times\ +\ 4\ +$

**Q6.** When Bubble sort algorithm is used, how many exchange operations are required to sort the following numbers in ascending order?

9, 2, 13, 21, 3, 0

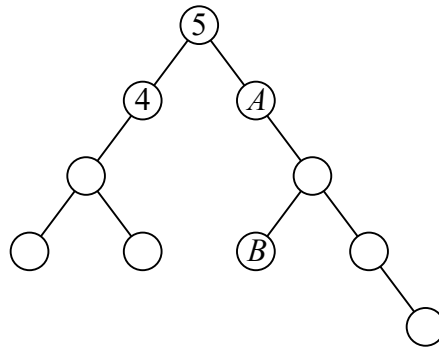
a) 7

b) 8

c) 9

d) 10

**Q7.** Values from 1 to 10 are assigned to 10 nodes in the binary tree below so that each node has a different value. In this assignment, the value of each node is greater than the values of the left child and all its descendants, and is less than the values of the right child and all its descendants. Which of the following is a combination of values assigned to node  $A$  and node  $B$ ?



- a)  $A = 6, B = 7$
- c)  $A = 7, B = 8$

- b)  $A = 6, B = 8$
- d)  $A = 7, B = 9$

**Q5.** The expression shown below is written in postfix (reverse Polish) notation. What is the value of this expression? Here, the numbers are in decimal, and the symbols '+', '-', '\*', and '/' represent addition, subtraction, multiplication, and division operators.

100 5 6 2 + \* 12 4 / - - 36 -

a) 18

b) 21

c) 27

d) 5

**Q8.** For a two-dimensional integer array  $a$ , whose element  $a(i, j)$  is of value  $2i + j$ , what is the value  $a(a(1, 1) \times 2, a(2, 2) + 1)$ ?

a) 12

b) 13

c) 18

d) 19

**Q9.** A recursive function  $f(n)$  is defined as follows for any natural number  $n$ . What is the value  $f(5)$ ?

$$f(n) = \begin{cases} 1 & (n \leq 1) \\ n + f(n-1) & (\text{otherwise}) \end{cases}$$

a) 6

b) 9

c) 15

d) 25

**Q7.** Let  $A$  be an array of integers of size 10, whose  $i^{\text{th}}$  entry is represented by  $A[i]$  for  $i = 0$  to 9, and its initial value is 0. For a positive integer  $k$ , the rules below determine the entry in which the value  $k$  is stored. When the integers 16, 43, 73, 24, and 85 are processed in this order, in which entry is the last value 85 stored? Here,  $x \bmod y$  represents the remainder after the division of  $x$  by  $y$ .

[Rules]

- (1) If  $A[k \bmod 10] = 0$ , then store  $k$  in  $A[k \bmod 10]$ .
- (2) Otherwise, if  $A[(k + 1) \bmod 10] = 0$ , then store  $k$  in  $A[(k + 1) \bmod 10]$ .
- (3) Otherwise, if  $A[(k + 4) \bmod 10] = 0$ , then store  $k$  in  $A[(k + 4) \bmod 10]$ .
- (4) Otherwise, discard  $k$ .

- a)  $A[3]$                       b)  $A[5]$                       c)  $A[6]$                       d)  $A[9]$

**Q5.** What is the value of the following expression in Reverse Polish Notation?

$$9 \ 2 \ 1 \ + \ - \ 3 \ \times$$

a) 0

b) 4

c) 10

d) 18



**Q6.** Function  $\text{mod}(x, y)$  is defined as the remainder of the division of  $x$  by  $y$ . By using this as a hash function, a 5-digit decimal number " $a_1a_2a_3a_4a_5$ " is stored in the array shown below at the position  $\text{mod}(a_1+a_2+a_3+a_4+a_5, 13)$ . What is the position of the number 54321 to be stored?

Position	Array
0	
1	
2	
$\vdots$	$\vdots$
11	
12	

a) 1

b) 2

c) 7

d) 11

**Q7.** For a pair of a queue and a stack, two operations “pop\_enq” and “deq\_push” are defined as follows:

pop\_enq : pops an item from the stack and puts it into the queue

deq\_push : takes an item from the queue and pushes it into the stack

When four items  $A$ ,  $B$ ,  $C$ , and  $D$  are stored in the queue, what is the minimum number of deq\_push operations required in order to reverse the order of the four items by using only these two operations?

a) 2

b) 3

c) 4

d) 5

**Q8.** In order to sort the sequence “98, 12, 4, 56, 34, 23” in ascending order by Bubble Sort algorithm, how many exchange operations are required?

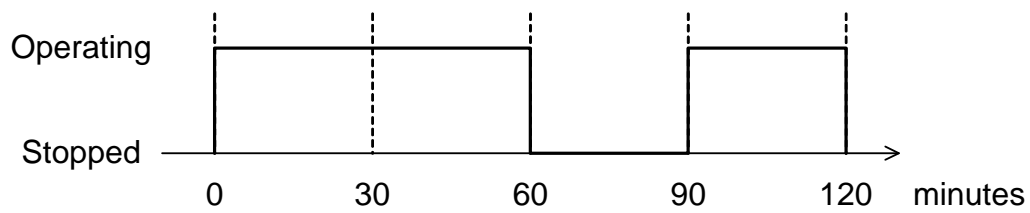
a) 5

b) 7

c) 9

d) 11

**Q23.** A device, which operates at a 100V household power supply and through which a current of 10 A flows during operation, is operated from 0 minutes to 120 minutes as shown in the figure below. How much electrical energy, in watt-hour, is consumed at this time? Here, the value of the voltage and current is the effective value, and no current flows when the device stops. Moreover, the power factor is 1.



- a) 1,000                      b) 1,200                      c) 1,500                      d) 2,000

**Q8.** 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

**Q10.** As shown in the table below, there are a total of 86 coins that are composed of five types of coins. Of those 86 coins, 60 coins are picked up so that the total value can be maximized. What is the total value in dollars? Here, 100 cents are equivalent to 1 dollar.

Type of coin	Number of coins
5-cent	20
10-cent	30
20-cent	25
50-cent	10
1-dollar	1

- a) 6                      b) 9                      c) 10.5                      d) 13.4

**Q5.** For the post-order traversal of a binary search tree where the left and right subtrees of the root node contain 1000 and 100 nodes respectively, which of the following is the number of nodes that are processed before the root node is visited?

- a) 0                      b) 100                      c) 1000                      d) 1100

**Q6.** When the procedure shown below is executed in listed order, what is stored in variable  $y$ ? Here, the stack and queue structures are initially empty, and four types of operations are defined as shown below.

[Operations]

push ( $x$ ): Put value  $x$  in the stack.  
pop ( ): Retrieve the value from the stack.  
enq ( $x$ ): Put value  $x$  in the queue.  
deq ( ): Retrieve the value from the queue.

[Procedure]

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

- a) 1                      b) 2                      c) 3                      d) 4



**Q7.** When the selection sort algorithm is used for sorting the dataset “2, 4, 6, 8, 10, 12, 14, 14” in descending order, how many data exchanges occur during the sorting process?

a) 4

b) 5

c) 6

d) 7

**Q22.** A power supply unit has a rated output power of 500 watts and an efficiency of 80%. In order to obtain an output power of 500 watts from this power supply unit, how many watts is the minimum input power?

- a) 100                      b) 400                      c) 625                      d) 900

- Q8.** When the hash function “ $x \bmod 13$ ” for a given key  $x$  is used to store five keys 367, 25, 82, 66, and 13 sequentially in the one-dimensional array shown below, which of the following is the appropriate combination of indices where the keys 82 and 13 are stored? Here, if the index location specified by a hash value is already occupied, the array is searched forward from that location to find the next empty location.

Index	0	1	2	3	4	5	6	7	8	9	10	11	12
Element	91				43							362	

	Key = 82	Key = 13
a)	4	0
b)	4	1
c)	5	1
d)	5	2

**Q3.** A chemical manufacturer has a plan to deliver 500 liters of a 24% acid solution. However, the manufacturer has only two types of acid solutions available in its stock, which are 40% (Type A) and 20% (Type B). How many liters of each acid solution must be mixed to make 500 liters of a 24% acid solution?

UNIT: liter

	Type A	Type B
a)	100	400
b)	200	300
c)	300	200
d)	400	100

**Q7.** There is a three-dimensional array  $A$  starting with  $A[1, 1, 1]$  and ending with  $A[3, 5, 7]$ , and consecutive integers starting with 0 are stored in ascending order. What is the maximum value (in hexadecimal) of the integers that can be stored in the array? Here, each number in the answer list is written in radix notation.

a)  $68_{16}$

b)  $69_{16}$

c)  $104_{16}$

d)  $105_{16}$

**Q9.** When a series of data shown below is searched using the binary search algorithm, what is the minimum number of comparisons needed to find a value of 5?

2, 5, 15, 16, 27, 27, 28, 40, 41, 51, 52, 55, 55, 57, 67, 79

- a) 1                      b) 2                      c) 3                      d) 4

**Q8.** When a two-dimensional array  $A(5,5)$  is mapped onto computer memory (i.e. one-dimensional array) in row-major (row-directional) order or column-major (column-directional) order, how many elements occupy the same memory addresses in both cases? Here, the first element  $A(1,1)$  is mapped onto the same starting memory address in either case.

- a) 2                      b) 3                      c) 4                      d) 5

**Q10.** When the series of stack operations below is performed on an empty stack, which of the following is the data that is read out by the last READ operation? Here, “PUSH  $x$ ” is the operation to put data  $x$  in the stack, “POP” is used to retrieve data from the stack, and “READ” is used to read data from the top of the stack without removing the original data.

PUSH 2 → READ → PUSH 3 → PUSH 6 → POP → READ → PUSH 4  
→ READ → PUSH 7 → PUSH 5 → POP → POP → READ

a) 2

b) 3

c) 4

d) 6



**Q11.** The function  $f(n)$  is recursively defined as an operation on the set of natural numbers (including 0) as shown below.

$$f(n) = \begin{cases} 0 & (n = 0) \\ f(n-1) + n & (n \geq 1) \end{cases}$$

What is the value of  $f(100)$ ?

- a) 4950                      b) 5049                      c) 5050                      d) 5051

**Q3.** How many multiplications at a minimum must be performed in order to calculate the polynomial expression " $x^4 - 2x^3 + 5x^2 + x - 6$ "?

a) 2

b) 3

c) 5

d) 6

**Q5.** When the expression  $(A - 2 \times (B + C) - D \times E) \times F$  in conventional infix notation is converted to the prefix expression, which of the following represents the resulting expression?

a)  $A2BC + \times - DE \times - F \times$

b)  $A2BC + \times - DE \times F - \times$

c)  $\times - - A \times 2 \times B + CDEF$

d)  $\times - - A \times 2 + BC \times DEF$

**Q6.** There is a two-dimensional array  $A$  with ten rows and ten columns. Each element in the array is two bytes long and is stored sequentially in memory in the customary “horizontal row first and vertical column second” order. When the first element  $A(1,1)$  is stored in memory address 500 that is represented in hexadecimal, what is the memory address of  $A(3,5)$  in hexadecimal?

- a) 518                      b) 530                      c) 548                      d) 554

**Q7.** A leap year in the Gregorian calendar includes an extra day at the end of February. Any year that is divisible by 4 and does not end in 00 is a leap year. Years ending in 00 are leap years only if they are divisible by 400. How many leap years are there between 1895 and 2011 in the Gregorian calendar?

- a) 27                      b) 28                      c) 29                      d) 30

**Q6.** When the runtime complexity of an algorithm is represented by  $n^2$ , which of the following is the running time for the algorithm to process one million elements? Here,  $n$  is the number of elements to be processed by this algorithm, and it takes 1 nanosecond to process only one element.

- |                 |                  |
|-----------------|------------------|
| a) 1 nanosecond | b) 1 millisecond |
| c) 1 second     | d) 1,000 seconds |

**Q9.** After seven keys 15, 11, 16, 2, 17, 22, 13 are sequentially stored in an empty hash table where the chain method is used for resolving collisions, how many comparisons are needed to search for the key 22 in the table? Here, the hash table size is 5, and the hash function " $x \bmod 5$ " is used for the key  $x$ . In the chain method, each table entry has a linked list, and synonymous keys are stored at the tail of each linked list.

- a) 1                      b) 2                      c) 3                      d) 4

**Q6.** When a set of values “5, 4, 3, 2, 8, 6, 0, 1, 9, and 7” is inserted in this order to create a binary search tree, which of the following represents the sequence of node values visited in the post-order traversal of the binary search tree?

a) 0 1 2 3 4 5 6 7 8 9

b) 1 0 2 3 4 7 6 9 8 5

c) 5 4 3 2 0 1 8 6 7 9

d) 5 4 8 3 6 9 2 7 0 1



**Q7.** There is a queue with eight cells and two pointers as shown below.

0	1						
		6	8	15			

Start pointer: 2

End pointer: 4

At this point, three values 6, 8, and 15 are stored in the queue. The start and end pointers indicate the location of the first and last data values respectively. After the series of operations described below is performed, which of the following is the appropriate combination of the two pointers? Here, upon reaching the end of the queue area, the pointers wrap around to the beginning of the queue again.

[Operations]

1. One value is enqueued.
2. Two values are dequeued.
3. Three values are enqueued.
4. One value is dequeued.

	Start pointer	End pointer
a)	0	5
b)	1	6
c)	5	0
d)	6	1

**Q8.** When the series of operations below is performed on an empty stack, which of the following is the data remaining on the stack? Here, “push  $x$ ” is the operation to save data  $x$  to the stack, and “pop” is used to retrieve data from the stack.

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

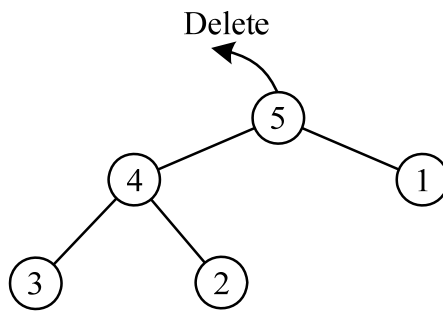
- a) 1 and 3                      b) 2 and 4                      c) 2 and 5                      d) 4 and 5

**Q9.** The steps below are used to sort a dataset in descending order by using a max heap.

[Steps]

1. Extract an element one by one from an unsorted dataset, and insert it into a max heap until all the elements are extracted and inserted.
2. Delete the root element from the max heap, and store it in a sorted dataset. Stop if all the elements are deleted. Otherwise, go to Step 3.
3. Move the rightmost element on the deepest level to the root. Go to Step 2 if the remaining elements are in the correct order as a max heap (that is, all the parent elements are greater than or equal to their corresponding child elements). Otherwise, go to Step 4.
4. Compare the replaced element with its children, and then exchange the element for its larger child. Go to Step 2 if all the elements are in the correct order as a max heap. Otherwise, continue Step 4 toward deeper levels.

In the max heap shown below, how many element exchanges in Step 4 are executed to build the next max heap after deletion of the root “5” in Step 2?



a) 0

b) 1

c) 2

d) 3

**Q10.** The Fibonacci sequence (0, 1, 1, 2, 3, 5, 8, 13, 21, 34, ...) can be defined recursively as follows:

$$f(x) = \begin{cases} 0 & (x=0) \\ 1 & (x=1) \\ f(x-1) + f(x-2) & (x>1) \end{cases}$$

How many times is the function  $f(x)$  called to calculate the Fibonacci number  $f(5)$ ?

- a) 1                      b) 3                      c) 5                      d) 15

**Q3.** Which of the following expressions can be used to calculate the quarter number (for example, “1” for January through March) for the n-th month of the year? Here, “n” ranges from “1” for January to “12” for December, and each fractional part of the resulting values is truncated.

a)  $\frac{n-1}{3}$

b)  $\frac{n-1}{3} + 1$

c)  $\frac{n}{3}$

d)  $\frac{n}{3} + 1$

**Q12.** When the binary search algorithm is applied to the list of data sorted in ascending order as shown below, how many comparisons are needed to find the fact that “104” is not in the list?

5   7   20   33   44   46   48   99   101   102   105

a) 3

b) 4

c) 5

d) 6

**Q15.** When the bubble sort algorithm is used for sorting the dataset (23, 43, 56, 12, 87, 14, 87, 15, 90, 23, 10) in descending order, how many data exchanges occur during the first pass?

- a) 7                      b) 8                      c) 9                      d) 10

**Q15.** When a list of seven elements shown below is rearranged in ascending order, which of the following sorting algorithms is completed with the minimum number of element exchanges?

15	1					9
----	---	--	--	--	--	---

- a) Bubble sort
- b) Insertion sort
- c) Selection sort
- d) Shell sort



**Q8.** There are  $n$  locks and  $n$  keys; the keys are mixed and need to specify which key belongs to which lock. Which of the following is the maximum number of trials to find the correct key for each lock? Here, one key can open only one lock.

a)  $n^2$

b)  $(n-1)!$

c)  $n!$

d)  $(n^2-n)/2$

**Q11.** There are three stacks  $A$ ,  $B$ , and  $C$  where stack  $A$  contains the values 1, 2, and 3; 3 is on the top of the stack, and stacks  $B$  and  $C$  are empty. The stack command format is as follows:

$\langle \text{stack command} \rangle (\langle \text{stack name} \rangle, \langle \text{temporary variable} \rangle)$

What is the resulting content of stack  $A$  after executing the stack operations shown below? Each rightmost element in the option list represents the value on the top of the stack.

$\text{Pop}(A, x) \rightarrow \text{Push}(B, x) \rightarrow \text{Pop}(A, x) \rightarrow \text{Push}(C, x) \rightarrow \text{Pop}(A, x) \rightarrow \text{Push}(C, x)$   
 $\rightarrow \text{Pop}(B, x) \rightarrow \text{Push}(A, x) \rightarrow \text{Pop}(C, x) \rightarrow \text{Push}(B, x) \rightarrow \text{Pop}(C, x) \rightarrow \text{Push}(A, x)$   
 $\rightarrow \text{Pop}(B, x) \rightarrow \text{Push}(A, x)$

- a) 1, 2, 3                      b) 2, 1, 3                      c) 3, 1, 2                      d) 3, 2, 1

**Q12.** In a certain examination, the minimum and maximum scores are 31 and 95 respectively.

A one-dimensional array shown below is used to display the distribution of scores for all examinees, and each array element indicates the number of examinees whose scores are in the specified ranges. Which of the following is the most appropriate expression to calculate an array index for each score? Here, any digits after the decimal point of the resulting value are truncated to generate an integer as an index.

Array index	Score range
1	Score < 40
2	40 ≤ Score < 50
3	50 ≤ Score < 60
4	60 ≤ Score < 70
5	70 ≤ Score < 80
6	80 ≤ Score < 90
7	90 ≤ Score < 100

a)  $(\text{Score}/10)-3$

b)  $(\text{Score}/30)/10$

c)  $(\text{Score}-30)/10+1$

d)  $(\text{Score}-40)/10$

**Q14.** A recursive definition of a factorial function  $f(n)$  that calculates “ $n!$ ” can be represented as follows:

$$\begin{cases} f(n) = \boxed{A} & (n > 1) \\ f(n) = \boxed{B} & (n = 0) \end{cases}$$

Which of the following combinations should be inserted in the boxes  $A$  and  $B$ ? Here, “ $n$ ” is a non-negative integer.

	$A$	$B$
a)	$*f(n-1)$	0
b)	$*f(n+1)$	0
c)	$*f(n-1)$	1
d)	$*f(n+1)$	1

**Q6.** Which of the following numbers is a valid ISBN? Here, ISBN means the International Standard Book Number which is used to identify books, publishers, and bookstores. It consists of exactly 10 digits, and the rightmost digit is used for a check digit. The check digit is validated by using modulo 11 as follows:

- Multiply each digit from the first (leftmost) to the ninth by a weight from 10 to 2 respectively; the first digit is multiplied by 10, the second by 9, and so on.
- Calculate the sum of each product, and then add the check digit.
- Divide the resulting value by 11.
- If the resulting remainder is zero (0), the check digit is valid. Otherwise, it is invalid.

For example, in case of ISBN 0003194876, the check digit is validated as follows:

First 9 digits:	0	0	0	3	1	9	4	8	7
Weight from 10 to 2:	10	9	8	7	6	5	4	3	2
Each product and sum:	0	0	0	21	6	45	16	24	14
Add check digit:	= 126								
Total:	6								
	132								

The remainder of the division of 132 by 11 is 0, so this ISBN is valid.

- |               |               |
|---------------|---------------|
| a) 0071361283 | b) 0071361284 |
| c) 0071361285 | d) 0071361286 |

- Q8.** The formula shown below is represented in postfix (or reverse Polish) notation. Which of following is the resulting value of this formula?

$$5\ 1 - 3\ * 3\ 1 - 2\ * /$$

- a) 1                      b) 3                      c) 5                      d) 7

**Q14.** When a list of 7 elements shown below is rearranged in ascending order, which of the following sorting algorithms is completed with the minimum number of element exchanges?

3	5	12				
---	---	----	--	--	--	--

- a) Bubble sort
- b) Insertion sort
- c) Merge sort
- d) Shell sort

**Q7.** There is a four-digit number  $N_1N_2N_3C$  that is used for Customer Account Number (CAN). The right most digit “C” can be calculated as follows:

$$C = (N_1 * 3 + N_2 * 5 + N_3 * 7) \bmod 10$$

Which of the following is a correct CAN? Here,  $x \bmod y$  returns the remainder when  $x$  is divided by  $y$ .

a) 7714

b) 7715

c) 9690

d) 9695



**Q17.** Which of the following equations holds well in the postfix notation (or Reverse Polish Notation)? Here,  $x$ ,  $y$ , and  $z$  are variables.

a)  $xy + z - = xyz + -$

b)  $xy - z + = xyz - +$

c)  $xy - z + = xyz - -$

d)  $xy - z - = xyz - -$

**Q18.** The following function  $f(n, k)$  exists:

$$f(n, k) = \begin{cases} 1 & (k=0) \\ f(n-1, k-1) + f(n-1, k) & (0 < k < n) \\ 1 & (k=n) \end{cases}$$

What is the value of  $f(4, 2)$ ?

a) 3

b) 4

c) 5

d) 6

- Q8.** There are two important operations on a stack: PUSH and POP. PUSH adds the new data to the top of the stack leaving previous data below, and POP removes and returns the current top data of the stack. When the operations shown below are sequentially executed, which of the following is the correct combination of the values  $x$  and  $y$ ? Here, the size of the stack is big enough to hold the entire data. “PUSH( $a$ )” inserts the data  $a$  into the stack, and “POP( $b$ )” removes the data  $b$  from the stack.

[Operations]

PUSH (5);

PUSH (3);

PUSH (6);

PUSH (1);

$x = \text{POP} ( )$ ;

PUSH (7);

$y = \text{POP} ( )$ ;

	$x$	$y$
a)	1	6
b)	1	7
c)	5	3
d)	5	7

**Q12.** There are two jugs; one is a 4-liter (4L) jug and the other is a 3-liter (3L) jug. Which of the following is the correct sequence to obtain exactly 2 liters of water in the 4L jug under the conditions shown below? Here,  $(x, y)$  indicates that the 4L jug contains  $x$  liters of water and the 3L jug has  $y$  liters of water.

[Conditions]

You can use only the 3L and 4L jugs.

You are allowed to fill up or empty either jug.

You are allowed to pour water from one jug to the other.

The jugs have no scale marks.

There is an ample supply of water.

- a)  $(0,0) \rightarrow (0,3) \rightarrow (3,0) \rightarrow (0,3) \rightarrow (4,2) \rightarrow (0,2) \rightarrow (2,0)$
- b)  $(0,0) \rightarrow (0,3) \rightarrow (3,0) \rightarrow (3,3) \rightarrow (4,2) \rightarrow (0,2) \rightarrow (2,0)$
- c)  $(0,0) \rightarrow (0,3) \rightarrow (3,3) \rightarrow (3,0) \rightarrow (4,2) \rightarrow (0,2) \rightarrow (2,0)$
- d)  $(0,0) \rightarrow (3,0) \rightarrow (0,3) \rightarrow (3,3) \rightarrow (0,2) \rightarrow (4,2) \rightarrow (2,0)$

**Q13.** Which of the following is the correct result produced by executing the program shown below? Here, the parameter “ $x$ ” is called by value, and the parameter “ $y$ ” is called by reference.

Main Program

$a = 2;$

$b = 3;$

$\text{sub}(b, a);$

Subprogram  $\text{sub}(x, y)$

$x = x + y;$

$y = x + y;$

$\text{return};$

a)  $a = 2, b = 3$

c)  $a = 7, b = 3$

b)  $a = 2, b = 5$

d)  $a = 7, b = 5$

**Q14.** The “prime number division remainder” method is a well-known hashing algorithm. In this method, a key value is divided by a number  $N$ , and the remainder which is also called a hash value is used directly as an index into the hash table.  $N$  is the largest prime number less than or equal to the size of the available addressable spaces. When the 20 addressable spaces are available, which of the following is the correct hash value calculated from the key value 136? Here, a prime number is one that cannot be divided evenly by any other number except one (1). 2, 3, 5, 7, 11, and 13 are the first few prime numbers.

- a) 0                      b) 1                      c) 3                      d) 16

**Q15.** In a certain computer, a bubble sort of an array of 200 data elements takes the same time as a quick sort of the array. In case of an array of 40,000 data elements, how many times faster is a quick sort than a bubble sort? Here, a bubble sort and a quick sort take time proportional to  $n^2$  and  $n \times \log_2 n$  respectively, and “ $n$ ” is the number of data elements.

- a) 10                      b) 50                      c) 100                      d) 200