[Multiple Choice Questions:]
1. If the array:
   6, 21, 35, 3, 6, 2, 13
   is added to a stack, in the order given, which of the following is the top of the stack?
   a) 2
   b) 6
   c) 3
   d) 13
   e) 35

2. If the array:
   6, 2, 7, 13, 5, 4
   is added to a queue, in the order given, which number will be the first number to be removed from the queue?
   a) 6
   b) 2
   c) 5
   d) 4

3. The **pop** operation throws a **StackException** when it tries to ______.
   a) add an item to an empty stack
   b) add an item to an array-based implementation of a stack that is already full
   c) delete an item from an array-based implementation of a stack that is already full
   d) delete an item from an empty stack

4. The **push** operation throws a **StackException** when it tries to ______.
   a) add an item to an empty stack
   b) add an item to an array-based implementation of a stack that is already full
   c) delete an item from an array-based implementation of a stack that is already full
   d) delete an item from an empty stack

5. A pointer-based stack must use a(n) ______.
   a) integer variable that defines the top of the stack
   b) integer variable that defines the maximum size of the stack
   c) compiler-generated copy constructor
   d) explicit copy constructor

6. Which of the following is NOT true about converting infix expressions to postfix expressions?
   a) the operands always stay in the same order with respect to one another
   b) the operators always stay in the same order with respect to one another
   c) an operator will move only “to the right” with respect to the operands
   d) all parentheses are removed

7. Typically, ______ are used by a compiler to implement recursive methods.
   a) linked-lists
   b) arrays
   c) stacks
   d) queues

8. Which of the following ADTs is like a line of people?
   a) list
   b) stack
   c) queue
   d) tree

9. In a queue, items can be added ______.
   a) only at the front of the queue
   b) only at the back of the queue
   c) either at the front or at the back of the queue
   d) at any position in the queue

10. In the STL, classes whose implementations use other classes are called ______.
    a) base containers
    b) basic classes
    c) adaptor containers
    d) interface containers
11. Which of the following is true about a time-driven simulation of a bank?
   a) arrival times are obtained from an input file
   b) transaction times are obtained from an input file
   c) currentTime is incremented by 1 to simulate the ticking of a clock
   d) no action is required between events

12. ______ is the ability of a class to derive properties from a previously defined class.
   a) Encapsulation
   b) Simulation
   c) Inheritance
   d) Polymorphism

13. The class from which another class is derived is known as the ______.
    a) base class
    b) subclass
    c) child class
    d) final class

14. A subclass inherits all of the following members of its superclass EXCEPT ______.
    a) public methods
    b) data fields
    c) constructors and destructor
    d) protected methods

15. ______ enables the reuse of existing classes.
    a) Encapsulation
    b) Inheritance
    c) Polymorphism
    d) Simulation

16. A ______ function is one that a derived class can override.
    a) final
    b) base
    c) static
    d) virtual

17. Dynamic binding is also known as ______.
    a) early binding
    b) late binding
    c) template binding
    d) inheritance binding

18. ______ is the ability of a variable name to represent, during program execution, instances of different but related classes that descend from a common superclass.
    a) Inheritance
    b) Containment
    c) Polymorphism
    d) Encapsulation

19. Declaring a nonmember function as a ______ function to a class allows that function to access to all of the private and protected members of the class.
    a) const
    b) global
    c) friend
    d) private

20. Assuming a linked list of n nodes, the code fragment:
    Node *cur = head;
    while (cur != null) {
        cout << curr->item << endl;
        cur = cur->next;
    } // end while
    requires ______ assignments.
    a) n
    b) n – 1
    c) n + 1
    d) 1

21. Assuming a linked list of n nodes, the code fragment:
    Node *cur = head;
    while (cur != null) {
        cout << curr->item << endl;
cur = cur->next;
} // end while
requires ______ comparisons.

a) n  
b) n – 1  
c) n + 1  
d) 1

22. The solution to the Towers of Hanoi problem with n disks requires \(2^n – 1\) moves. If each move requires the same time \(m\), the solution requires ______ time units.

a) \(2^n – 1\)  
b) \((2^n – 1) + m\)  
c) \((2^n – 1) / m\)  
d) \((2^n – 1) * m\)

23. The solution to the Towers of Hanoi problem with n disks requires \(2^n – 1\) moves. If each move requires the same time \(m\), the solution requires ______ time units.

a) \(2^n – 1\)  
b) \((2^n – 1) + m\)  
c) \((2^n – 1) / m\)  
d) \((2^n – 1) * m\)

24. An exponential algorithm has the growth-rate function ______.

a) \(O(n^2)\)  
b) \(O(n^3)\)  
c) \(O(2^n)\)  
d) \(O(\log_2 n)\)

25. Given the following array:
   4 15 8 3 28 21
   which of the following represents the array after the second swap of the selection sort?

a) 4 3 8 15 21 28  
b) 4 15 8 3 21 28  
c) 3 4 8 15 21 28  
d) 21 4 3 8 15 28

26. Given the fact that a selection sort of \(n\) items requires \(n^2/2 + 5 * n/2 – 3\) major operations, the selection sort is ______.

a) \(O(n)\)  
b) \(O(1)\)  
c) \(O(n^2)\)  
d) \(O(n^2/2)\)

Chapter 9 Questions

Multiple Choice Questions:

27. Which of the following is NOT part of the human cost of developing a computer program?

a) the efficiency of a program  
b) the readability of a program  
c) the modifiability of a program  
d) the maintainability a program

28. Algorithm analysis should be independent of all of the following EXCEPT ______.

a) the programming style used in the implementation of the algorithm  
b) the computer used to run a program which implements an algorithm  
c) the number of significant operations in an algorithm  
d) the test data used to test a program which implements an algorithm

29. Assuming a linked list of \(n\) nodes, the code fragment:

```c
Node *cur = head;
while (cur != null) {
    cout << cur->item << endl;
```
cur = cur->next;
}  // end while

requires ______ assignments.
   a) n
   b) n - 1
   c) n + 1
   d) 1

30. Assuming a linked list of n nodes, the code fragment:
   Node *cur = head;
   while (cur != null) {
      cout << curr->item << endl;
      cur = cur->next;
   }  // end while

requires ______ comparisons.
   a) n
   b) n - 1
   c) n + 1
   d) 1

31. The solution to the Towers of Hanoi problem with n disks requires $2^n - 1$ moves. If each move requires the same
time m, the solution requires ______ time units.
   a) $2^n - 1$
   b) $(2^n - 1) + m$
   c) $(2^n - 1)/m$
   d) $(2^n - 1) \times m$

32. Consider an algorithm that contains loops of the form:
   for (i = 1 through n) {
      for (j = 1 through i) {
         for (k = 1 through 10) {
            Task T
         }  // end for
      }  // end for
   }  // end for

If task T requires $t$ time units, the innermost loop on k requires ______ time units.
   a) j
   b) 10
   c) k * t
   d) 10 * t

33. Consider an algorithm that contains loops of the form:
   for (i = 1 through n) {
      for (j = 1 through i) {
         for (k = 1 through 10) {
            Task T
         }  // end for
      }  // end for
   }  // end for

If task T requires $t$ time units, the loop on j requires ______ time units.
   a) 10 * t
   b) $(10 * t) + i$
   c) $10 * t * i$
   d) $t * i$

34. Which of the following can be used to compare two algorithms?
   a) growth rates of the two algorithms
   b) implementations of the two algorithms
   c) test data used to test programs which implement the two algorithms
35. Algorithm efficiency is typically a concern for ______.
   a) small problems only
   b) large problems only
   c) medium sized problems only
   d) problems of all sizes

36. If a problem of size n requires time that is directly proportional to n, the problem is ______.
   a) O(1)
   b) O(n)
   c) O(n^2)
   d) O(2n)

37. The value of which of the following growth-rate functions grows the fastest?
   a) O(n)
   b) O(n^2)
   c) O(1)
   d) O(log_2n)

38. The value of which of the following growth-rate functions grows the slowest?
   a) O(n)
   b) O(n^2)
   c) O(1)
   d) O(log_2n)

Answer:

39. A growth-rate function of ______ implies a problem whose time requirement is constant.
   a) 1
   b) n
   c) 2^n
   d) log_2n

Answer:

40. Which of the following growth-rate functions indicates a problem whose time requirement is independent of the size of the problem?
   a) O(n)
   b) O(log_2n)
   c) O(2^n)
   d) O(1)

Answer:

41. A linear algorithm has the growth-rate function ______.
   a) O(log_2n)
   b) O(2^n)
   c) O(n)
   d) O(1)

Answer:

42. A quadratic algorithm has the growth-rate function ______.
   a) O(n^2)
   b) O(n^3)
   c) O(2^n)
   d) O(log_2n)

Answer: 

43. An exponential algorithm has the growth-rate function ______.
   a) O(n^2)
   b) O(n^3)
   c) O(2^n)
44. In the best case, a sequential search is ______.
   a) O(n)
   b) O(1)
   c) O(log₂n)
   d) O(n²)
Answer:

45. In the worst case, a binary search is ______.
   a) O(n)
   b) O(1)
   c) O(log₂n)
   d) O(n²)
Answer:

46. The selection sort is continued until ______ of the n items in an array have been swapped.
   a) n/2
   b) n – 2
   c) n – 1
   d) n
Answer:

47. Given the following array:
   4 15 8 3 28 21
   which of the following represents the array after the second swap of the selection sort?
   a) 4 3 8 15 21 28
   b) 4 15 8 3 21 28
   c) 3 4 8 15 21 28
   d) 21 4 3 8 15 28
Answer:

48. Given the fact that a selection sort of n items requires \( \frac{n^2}{2} + 5 \times \frac{n}{2} - 3 \) major operations, the selection sort is ______.
   a) O(n)
   b) O(1)
   c) O(n²)
   d) O(n²/2)
Answer:

49. The ______ compares adjacent items and exchanges them if they are out of order.
   a) selection sort
   b) binary search
   c) bubble sort
   d) quicksort
Answer: .

50. The quicksort is ______ in the worst case.
   a) O(n²)
   b) O(n³)
   c) O(n * log₂n)
   d) O(log₂n)

Chapter 10 Questions
Multiple Choice Questions:

51. The _____ ADT is value-oriented.
   a) list
   b) sorted list
   c) stack
   d) queue
   e) binary tree

Answer:

52. The ADT stack manages an association between data items and the ______ of the data items.
   a) names
   b) values
   c) sizes
   d) positions

Answer:

53. The operations of the ADT sorted list are based upon the ______ of data items.
   a) names
   b) values
   c) sizes
   d) positions

Answer:

54. The ______ is a position-oriented ADT that is not linear.
   a) sorted list
   b) queue
   c) binary tree
   d) list

Answer:

55. Which of the following ADT is position-oriented?
   a) binary tree
   b) sorted list
   c) table
   d) priority queue

Answer:

56. A node of a tree is called a(n) ______.
   a) edge
   b) root
   c) branch
   d) vertex

Answer: .

57. The lines between the nodes of a tree are called ______.
   a) branches
   b) edges
   c) arches
   d) subtrees

Answer: .

58. The node that is directly above node n in a tree is called the ______ of node n.
   a) root
   b) leaf
   c) parent
   d) child

Answer: .

59. A node directly below node n in a tree is called a ______ of node n.
60. In a tree, the children of the same parent are called ______.
   a) leafs
   b) siblings
   c) roots
   d) contemporaries

   Answer:

61. Each node in a tree has ______.
   a) exactly one parent
   b) at most one parent
   c) exactly two parents
   d) at most two parents

   Answer: .

62. A node on the path from the root to node n is a(n) ______ of node n.
   a) ancestor
   b) descendant
   c) subtree
   d) leaf

   Answer: .

63. A descendant of node n is a node on a path from node n to ______.
   a) the root
   b) a leaf
   c) a sibling of node n
   d) a child of node n

   Answer: .

64. A subtree of node n is a subtree rooted at ______.
   a) node n
   b) the parent of node n
   c) a child of node n
   d) a sibling of node n

   Answer: .

65. Each node in a binary tree has ______.
   a) exactly one child
   b) at most one child
   c) exactly two children
   d) at most two children

   Answer: .

66. The ______ of a tree is the number of nodes on the longest path from the root to a leaf.
   a) height
   b) length
   c) width
   d) age

   Answer: .

67. In a ______ of height h, all nodes that are at a level less than h have two children each.
   a) general tree
   b) binary tree
   c) full binary tree
   d) complete binary tree

   Answer: .
68. A ______ of height h is full down to level h – 1, with level h filled in from left to right.
   a) full binary tree
   b) complete binary tree
   c) balanced binary tree
   d) general tree
Answer: .

69. In ______, the left and right subtrees of any node have heights that differ by at most 1.
   a) all trees
   b) all binary trees
   c) n-ary trees
   d) balanced binary trees
Answer: .

70. Which of the following is NOT a property of a complete binary tree of height h?
   a) all nodes at level h – 2 and above have two children each
   b) when a node at level h – 1 has children, all nodes to its left at the same level have two children each
   c) when a node at level h – 1 has one child, it is a left child
   d) all leaves are at level h
Answer: .

71. The traversal of a binary tree is ______.
   a) O(n)
   b) O(1)
   c) O(n^2)
   d) O(log_2n)
Answer: .

72. The ______ defines the visit function argument for the function header below:
   void inorder(TreeNode *treePtr, FunctionType visit);
   a) binary tree header file
   b) tree node class
   c) friend class of the binary tree
   d) client
Answer: .

73. In an array based representation of a complete binary tree, which of the following represents the left child of node
   tree[i] (index starts from 0)?
   a) tree[i+2]
   b) tree[i-2]
   c) tree[2*i+1]
   d) tree[2*i+2]
Answer: .

74. Traversal functions in a pointer-based representation of a binary tree should be declared as ______ members to enable recursion.
   a) private
   b) protected
   c) const
   d) public
Answer: b.

75. The maximum number of comparisons for a retrieval operation in a binary search tree is the ______.
   a) length of the tree
   b) height of the tree
   c) number of nodes in the tree
   d) number of leaves in the tree
Answer:
76. The maximum height of a binary tree of \( n \) nodes is ______.
   a) \( n \)
   b) \( n / 2 \)
   c) \( (n / 2) - 2 \)
   d) \( \log_2(n + 1) \)
   Answer:

77. The minimum height of a binary tree of \( n \) nodes is ______.
   a) \( n \)
   b) \( n / 2 \)
   c) \( (n / 2) - 2 \)
   d) \( \lceil \log_2(n + 1) \rceil \)
   Answer:

78. A full binary tree with height 4 has ______ nodes.
   a) 7
   b) 8
   c) 15
   d) 31
   Answer:

79. What is the return type of the STL `equal_range` function?
   a) forward iterator
   b) pair `<iterator, iterator>`
   c) int
   d) bidirectional iterator
   Answer:

Chapter 11 Questions

Multiple Choice Questions:

80. Which of the following operations of the ADT table does NOT throw a `TableException`?
   a) `traverseTable`
   b) `tableDelete`
   c) `tableRetrieve`
   d) `tableInsert`
   Answer:

81. An array-based implementation of an ADT is a ______ implementation.
   a) vertical
   b) linear
   c) nonlinear
   d) compound
   Answer:

82. Which of the following is true about a linear implementation of a table?
   a) the unsorted implementations must insert a new item into its proper position as determined by the value of its search key
   b) the sorted implementations can insert a new item into any convenient location
   c) the sorted implementations maintain a count of the current number of items in the table
   d) the unsorted implementations do not maintain a count of the current number of items in the table
   Answer:

83. In the sorted linear implementation of a table, the proper position of a new item to be inserted is determined ______.
   a) by the data type of the item
   b) by the size of the item
   c) by the value of the item
   d) by the value of the search key of the item
   Answer:
84. A(n) ______ implementation of a table is nonlinear.
   a) list
   b) linked list
   c) binary search tree
   d) array

Answer: .

85. In an unsorted array-based implementation of the ADT table, the insertion operation is ______.
   a) O(1)
   b) O(n)
   c) O(n^2)
   d) O(log n)

Answer: .

86. In an unsorted array-based implementation of the ADT table, the retrieval operation is ______.
   a) O(1)
   b) O(n)
   c) O(n^2)
   d) O(log n)

Answer: .

87. The sorted, pointer-based implementation of the tableInsert operation is ______.
   a) O(1)
   b) O(n)
   c) O(n^2)
   d) O(log n)

Answer: .

88. Which of the following operations of the binary search tree implementation of the ADT tree is O(n)?
   a) insertion
   b) deletion
   c) retrieval
   d) traversal

Answer: d.

89. A priority queue orders its items by their ______.
   a) position
   b) value
   c) priority value
   d) size

Answer:

90. The first item to be removed from a priority queue is the item ______.
   a) in the front of the priority queue
   b) in the end of the priority queue
   c) with the highest value
   d) with the highest priority value

Answer:

91. The ______ operation is the most significant difference between the ADT priority queue and the ADT table.
   a) createPQueue
   b) pqIsEmpty
   c) pqInsert
   d) pqDelete

Answer:

92. In a linear implementation of the priority queue based on a linked list, the item with the highest priority value is located ______.
   a) at the beginning of the linked list
   b) at the end of the linked list
93. In a binary search tree implementation of the ADT table, the item with the highest priority value is always in the ______.
   a) root of the tree
   b) leftmost node of the tree
   c) rightmost node of the tree
   d) leftmost node at level 1 of the tree
Answer: a.

94. A heap in which the root contains the item with the largest search key is called a ______.
   a) minheap
   b) maxheap
   c) complete heap
   d) binary heap
Answer: b.

95. A heap in which the root contains the item with the smallest search key is called a ______.
   a) minheap
   b) maxheap
   c) complete heap
   d) binary heap
Answer: a.

96. A heap is a ______.
   a) general tree
   b) table
   c) full binary tree
   d) complete binary tree
Answer: c.

97. In an array-based implementation of a heap, the heapDelete operation is ______.
   a) O(1)
   b) O(n)
   c) O(n²)
   d) O(log n)
Answer:

98. In an array-based implementation of a heap, the parent of the node in items[i] is always stored in ______.
   a) items[i/2]
   b) items[(i-1)/2]
   c) items[i-2]
   d) items[(i-2)/2]
Answer: b.

99. In an array-based implementation of a heap, the heapInsert operation is ______.
   a) O(1)
   b) O(n)
   c) O(n²)
   d) O(log n)
Answer:

100. The heapsort is ______ in the worst case.
    a) O(n)
    b) O(log n)
    c) O(n * log n)
    d) O(n²)
Answer:
101. The heapsort is ______ in the average case.
   a) O(1)
   b) O(n)
   c) O(log n)
   d) O(n * log n)
Answer:

102. Which of the following is true about the heapsort?
   a) the heapsort does not require a second array
   b) the heapsort is more efficient than the mergesort in the worst case
   c) the heapsort is more efficient than the mergesort in the average case
   d) the heapsort is better than the quicksort in the average case
Answer:

103. Which of the following STL containers provide subscripting through the [] operator?
   a) multiset
   b) priority_queue
   c) set
   d) map
Answer:  d.

Chapter 12 Questions

Multiple Choice Questions:

104. In the binary search tree implementation of the ADT table, the maximum number of comparisons required by the 
    tableInsert operation is equal to ______.
    a) the number of nodes in the binary search tree
    b) the height of the binary search tree
    c) the number of leaves in the binary search tree
    d) the number of internal nodes in the binary search tree
Answer:

105. The maximum height of a binary search tree of n nodes is ______.
    a) n
    b) n – 1
    c) n / 2
    d) \(\lceil\log_2(n + 1)\rceil\)
Answer:

106. All the nodes in a binary tree are ______.
    a) single nodes
    b) 1-nodes
    c) 2-nodes
    d) double nodes
Answer:  c.

107. A node that contains one data item and has two children is called a ______.
    a) 1-node
    b) 2-node
    c) single node
    d) double node
Answer:

108. Which of the following is NOT true about a red-black tree?
    a) it is balanced
    b) its insertion operation requires one pass from root to leaf

c) its deletion operation requires one pass from root to leaf
d) it requires more storage than a 2-3-4 tree

109. Operations which are used to maintain the balance of AVL trees are known as ______.
a) revolutions
b) rotations
c) hash functions
d) refractions

110. A(n) ______ maps the search key of a table item into a location that will contain the item.
a) hash function
b) hash table
c) AVL tree
d) red-black tree

111. The condition that occurs when a hash function maps two or more distinct search keys into the same location is called a(n) ______.
a) disturbance
b) collision
c) rotation
d) congestion

112. The sequence of locations in a hash table that a collision resolution scheme examines is known as a(n) ______ sequence.
a) iteration
b) hash
c) collision
d) probe

113. ______ is a collision-resolution scheme that searches the hash table sequentially, starting from the original location specified by the hash function, for an unoccupied location.
a) Linear probing
b) Quadratic probing
c) Double hashing
d) Separate chaining

114. ______ is a collision-resolution scheme that searches the hash table for an unoccupied location beginning with the original location that the hash function specifies and continuing at increments of 1^2, 2^2, 3^2, and so on.
a) Linear probing
b) Double hashing
c) Quadratic probing
d) Separate chaining

115. ______ is a collision-resolution scheme that uses an array of linked lists as a hash table.
a) Linear probing
b) Double hashing
c) Quadratic probing
d) Separate chaining

116. The load factor of a hash table is calculated as ______.
a) table size + current number of table items
b) table size – current number of table items
c) current number of table items * table size
d) current number of table items / table size
117. In the following HashMap class definition, which class represents a bucket that holds elements with the same hash value?

```
template <class Key, class T, class Hash>
class HashMap : private vector<map<Key, T> >

a) T  
b) Key  
c) map  
d) vector
```

Answer: .

Chapter 13 Questions

Multiple Choice Questions:

118. A graph consists of _____ sets.
   a) two  
b) three  
c) four  
d) five

Answer: .

119. A subset of a graph's vertices and edges is known as a _____.
   a) bar graph  
b) line graph  
c) subgraph  
d) circuit

Answer: .

120. Two vertices that are joined by an edge are said to be _____ each other.
   a) related to  
b) bordering  
c) utilizing  
d) adjacent to

Answer: .

121. A path is a sequence of _____ in a graph.
   a) vertices  
b) edges  
c) subgraphs  
d) cycles

Answer: .

122. All _____ begin and end at the same vertex and do not pass through any other vertices more than once.
   a) paths  
b) simple paths  
c) cycles  
d) simple cycles

Answer: .

123. Which of the following is true about a simple cycle?
   a) it can pass through a vertex more than once  
b) it can not pass through a vertex more than once  
c) it begins at one vertex and ends at another  
d) it passes through only one vertex

Answer: .

124. A graph is ______ if each pair of distinct vertices has a path between them.
   a) complete  
b) disconnected  
c) connected  
d) full
125. A graph is ______ if it has at least one pair of vertices without a path between them.
   a) complete  
   b) disconnected  
   c) connected  
   d) full  
Answer:  .

126. A complete graph has a(n) ____ between each pair of distinct vertices.
   a) edge  
   b) path  
   c) cycle  
   d) circuit  
Answer:  .

127. A ____ can have duplicate edges between vertices.
   a) spanning tree  
   b) connected graph  
   c) complete graph  
   d) multigraph  
Answer:  .

128. A self edge is also called a ____.
   a) cycle  
   b) loop  
   c) circuit  
   d) multigraph  
Answer:  .

129. The ____ of a weighted graph have numeric labels.
   a) vertices  
   b) edges  
   c) paths  
   d) cycles  
Answer:  .

130. The edges in a ____ indicate a direction.
   a) graph  
   b) multigraph  
   c) digraph  
   d) spanning tree  
Answer:  .

131. If there is a directed edge from vertex x to vertex y, which of the following can be concluded about x and y?
   a) y is a predecessor of x  
   b) x is a successor of y  
   c) x is adjacent to y  
   d) y is adjacent to x  
Answer:  .

132. A graph-traversal algorithm stops when ____.
   a) it first encounters the designated destination vertex  
   b) it has visited all the vertices that it can reach  
   c) it has visited all the vertices  
   d) it has visited all the vertices and has returned to the vertex that it started from  
Answer:  .

133. A ____ is the subset of vertices visited during a traversal that begins at a given vertex.
a) circuit  
b) multigraph  
c) digraph  
d) connected component

Answer: .

134. In the following STL declaration of an adjacency list, what does the map represent?
\[
\text{vector<map<int, int> > adjList;}
\]
a) first vertex (key), edge weight (value)  
b) second vertex (key), edge weight (value)  
c) first vertex (key), second vertex (value)  
d) first vertex (key), key (value)

Answer: .

135. An iterative DFS traversal algorithm uses a(n) ______.
a) list  
b) array  
c) queue  
d) stack

Answer: .

136. In an STL implementation of an iterative BFS traversal, the ______ container stores the visited vertices.
a) set  
b) stack  
c) queue  
d) map

Answer: .

137. A ______ order is a list of vertices in a directed graph without cycles such that vertex x precedes vertex y if there is a directed edge from x to y in the graph.
a) graphical  
b) topological  
c) hierarchal  
d) spatial

Answer: .

138. A ______ is an undirected connected graph without cycles.
a) tree  
b) multigraph  
c) digraph  
d) connected component

Answer: .

139. A connected undirected graph that has n vertices must have at least ______ edges.
\[
a) n  
b) n - 1  
c) n / 2  
d) n * 2
\]

Answer: .

140. A connected undirected graph that has n vertices and exactly n – 1 edges ______.
a) cannot contain a cycle  
b) must contain at least one cycle  
c) can contain at most two cycles  
d) must contain at least two cycles

Answer: .
141. A connected undirected graph that has \( n \) vertices and more than \( n - 1 \) edges ______.
   a) cannot contain a cycle
   b) must contain at least one cycle
   c) can contain at most two cycles
   d) must contain at least two cycles

Answer: .

142. A tree with \( n \) nodes must contain _____ edges.
   a) \( n \)
   b) \( n - 1 \)
   c) \( n - 2 \)
   d) \( n / 2 \)

Answer: .

143. The sum of the weights of the edges of a path can be called all of the following EXCEPT ______.
   a) length
   b) weight
   c) height
   d) cost

Answer: .

144. A ______ is a special cycle that passes through every vertex in a graph exactly once.
   a) multigraph
   b) tree
   c) spanning tree
   d) circuit

Answer: .

1. Consider the following binary search tree. Show the binary search tree after deletion of node *. 
   **Explain** the algorithm that you used.

![Binary Search Tree Diagram]

**Answer:**
Problem 2: Consider the max heap which is represented by the array $A$. Show the max heap in $A$ after three heapDelete() operations (show max heap after each operation).

Array $A$:

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>60</td>
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<td>50</td>
<td>45</td>
<td>35</td>
<td>10</td>
</tr>
<tr>
<td>20</td>
<td>25</td>
<td>40</td>
<td>15</td>
<td>30</td>
<td></td>
</tr>
</tbody>
</table>

Answer:

Problem 3: Show the DFS() and BFS() spanning trees for the following graph by using starting vertex A. Assume adjacent vertices are accessed in increasing alphabetical order.

Answer:

DFS Spanning tree:

BFS Spanning tree:
Problem 4: Show the minimum spanning tree for the following graph by using Kruskal Algorithm.

5. Trace the mergesort algorithm as it sorts the array
   \[ A = (12, 2, 16, 30, 8, 4, 10, 20) \] into ascending order.

6. Trace the quicksort algorithm as it sorts the array
   \[ A = (12, 2, 16, 30, 8, 4, 10, 20) \] into ascending order. Use the last element as a pivot value. (as shown at the course note)

7. Fill in the worst case performance in the table below.

<table>
<thead>
<tr>
<th></th>
<th>Insert</th>
<th>Delete</th>
<th>Retrieve</th>
<th>Find Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sorted Array Based List</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balanced BST</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max Heap</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hash</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

8. Explain the difference of ADT and data structure.

9. Explain the difference of set vs. hash-set about their implementation, performance and limitations.

10. When you are developing your own priority queue, will you use heap or sorted array? Explain your choice and justification.

11. Explain the difference of adjacency matrix and adjacency list. And in which situation would you use one over the other? Explain the reason.

12. Briefly describe the topological sorting algorithm on a DAG.
13. Explain what is skip-list, its performance, and what is the reason not to use rigid pattern and what is the solution for the problem?

14. Write a DFS algorithm of a given graph.

15. Write a BFS algorithm

16. Write an Kruskal’s algorithm to find minimum spanning tree.