

Multiple Choice. Write your answer to the LEFT of each problem. 4 points each

- The expected time for insertion sort for n keys is in which set? (All $n!$ input permutations are equally likely.)
 A. $\Theta(\log n)$ B. $\Theta(n)$ C. $\Theta(n \log n)$ D. $\Theta(n^2)$
- Suppose you are given a large table with n integers in descending order, possibly with repeated values. How much time is needed to determine the minimum value?
 A. $\Theta(1)$ B. $\Theta(\log n)$ C. $\Theta(n)$ D. $\Theta(n \log n)$
- Suppose you have correctly determined some c and n_0 to prove $g(n) \in \Omega(f(n))$. Which of the following is not necessarily true?
 A. c may be decreased B. c may be increased C. n_0 may be increased D. $f(n) \in O(g(n))$
- Suppose you are using the substitution method to establish a Θ bound on a recurrence $T(n)$ and you already know that $T(n) \in \Omega(\log n)$ and $T(n) \in O(n^3)$. Which of the following cannot be shown as an improvement?
 A. $T(n) \in O(\log n)$ B. $T(n) \in \Omega(n^2)$ C. $T(n) \in \Omega(n^3)$ D. $T(n) \in O(1)$
- The function $n + \log n$ is in which set?
 A. $\Omega(n^2)$ B. $\Theta(\log n)$ C. $\Theta(n)$ D. $\Theta(n \log n)$
- Which of the following is not true?
 A. $n^2 \in O(n^3)$ B. $n \log n \in O(n^2)$
 C. $g(n) \in O(f(n)) \Leftrightarrow f(n) \in O(g(n))$ D. $\log n \in \Omega(\log \log n)$
- Suppose a binary search is to be performed on a table with 20 elements. The maximum number of elements that could be examined (probes) is:
 A. 4 B. 5 C. 6 D. 7
- The time to run the code below is in:

```
for (i=n; i>=0; i--)
  for (j=1; j<n; j=2*j+1)
    sum+=i+j;
```

 A. $\Theta(n \log n)$ B. $\Theta(n^2)$ C. $\Theta(n^3)$ D. $\Theta(n)$
- What is the definition of H_n ?
 A. $\Theta(\sqrt{n})$ B. $\sum_{k=1}^n k$ C. $\ln n$ D. $\sum_{k=1}^n \frac{1}{k}$ D. 49
- What is required when calling `union(find(i), find(j))` for maintaining disjoint subsets?
 A. i and j are leaders for different subsets
 B. i and j are in the same subset
 C. i and j are in different subsets
 D. i is the ancestor of j in one of the trees

Long Answer

- Use the substitution method to show that $T(n) = T\left(\frac{n}{2}\right) + n^2$ is in $O(n^2)$. (You do not need to show that $T(n)$ is in $\Omega(n^2)$.) 20 points
- Use the recursion-tree method to show that $T(n) = T\left(\frac{n}{2}\right) + n^2$ is in $\Theta(n^2)$. 20 points
- Two `int` arrays, A and B, contain m and n `ints` each, respectively, with $1 \leq m \leq n$. The elements within both of these arrays appear in **ascending order**, but duplicates are allowed.

Give C code for a $\Theta(n)$ algorithm to test that every value in A appears at least once in B and that every value in B appears at least once in A. If this holds, your code should return 1. If this does not hold, then your code should return 0. Your technique should operate “in place” using a small number of work variables and no additional arrays. (Details of input/output, allocation, declarations, error checking, and comments **are completely unnecessary**.) 20 points

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Test 2

Fall 2013

Multiple Choice. Write your answer to the LEFT of each problem. 4 points each

- Which of the following is not true for the activity scheduling problem?
 - There may be several optimal solutions.
 - The goal is to minimize the number of activities chosen.
 - The activities may have various durations.
 - The greedy solution is optimal.
- The time to fill in the dynamic programming matrix when computing the LCS for sequences of lengths m and n is:
 - $\Theta(n)$
 - $\Theta(m + n)$
 - $\Theta(n \log n)$
 - $\Theta(mn)$
- Which technique allows interfacing a priority queue with a dictionary?
 - Binary search tree
 - PQchange
 - Array of handles
 - Binary search
- An instance of *weighted* interval scheduling has been solved to give a schedule with k intervals. The same set of intervals (without the weights) is used as an instance of *unweighted* interval scheduling to give a schedule with p intervals. Which of the following could not occur?
 - $k < p$
 - $k > p$
 - $k = p$
 - the same intervals appear in both schedules
- The goal of the Huffman coding method is:
 - Maximize the compression for every string.
 - Minimize the expected bits per symbol.
 - Store a string within the leaves of a binary tree.
 - Construct an order-preserving tree.
- Suppose a value k appears for p entries in the cost function table (C) for an instance of the longest monotonically increasing subsequence problem. Going left-to-right across the corresponding input sequence values (y_j), which statement is true?
(Stated formally: For $i_1 < i_2 < \dots < i_p$, suppose $C_{i_1} = C_{i_2} = \dots = C_{i_p} = k$. Which statement is true regarding $y_{i_1}, y_{i_2}, \dots, y_{i_p}$?)
 - They are monotonically decreasing
 - They are monotonically increasing
 - They are strictly decreasing
 - They are strictly increasing
- A more accurate name for the subset sum problem is:
 - Combination sum
 - Indivisible, unbounded knapsack
 - Maximum achievable sum
 - Permutation sum
- Which of the following dynamic programming problems maximizes its cost function?
 - Optimal matrix multiplication
 - Weighted interval scheduling
 - Parking permits
 - Subset sum
- Which of the following is not true regarding a maxheap with 1000 elements?
 - Subscript 1 will store the maximum priority.
 - The left child for the node with subscript 200 is stored at subscript 400.
 - The right child for the node with subscript 405 is stored at subscript 911.
 - The parent for the node with subscript 500 is stored at subscript 250.
- Bottom-up heap construction is based on applying `fixDown` in the following fashion:

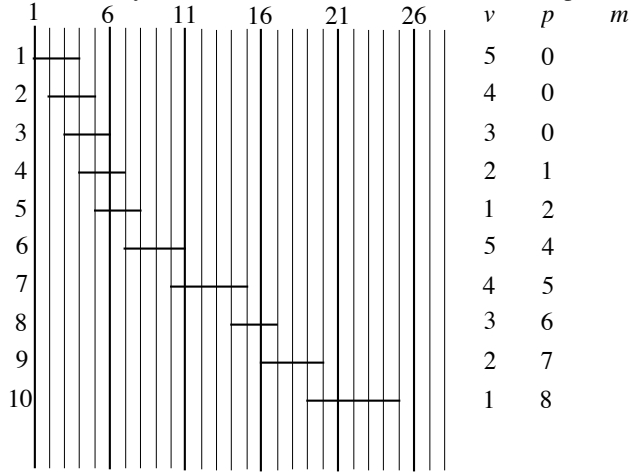
- A. In descending slot number order, for each slot that is a parent.
- B. $\frac{n}{2}$ times, each time from the root of the heap.
- C. $n - 1$ times, each time from the root of the heap.
- D. In ascending slot number order, for each slot that is a parent.

Long Answer

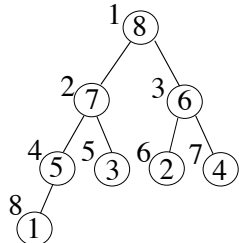
1. Give a Huffman code tree for the following symbols and probabilities. Besides the tree, be sure to compute the expected bits per symbol. 15 points

A	0.15
B	0.03
C	0.5
D	0.03
E	0.22
F	0.07

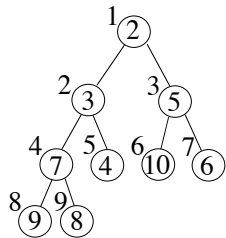
2. Use dynamic programming to solve the following instance of weighted interval scheduling. Be sure to indicate the intervals in your solution and the sum achieved. 15 points



3. a. Show the maxheap after performing PQdelmax. 8 points



b. Show the minheap after changing the priority at subscript 9 to 1. 7 points



4. Complete the following instance of the optimal matrix multiplication ordering problem, including the tree showing the optimal ordering. 15 points

- p[0]=6
- p[1]=2
- p[2]=4
- p[3]=3
- p[4]=2

	1	2	3	4
1	0	48	60	???
2	-----	0	24	36

3 ----- 0 0 24 3
 4 ----- 0 0

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Test 3

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Fall 2013

Multiple Choice. Write your answer to the LEFT of each problem. 4 points each

- If POP is implemented as return stack[--SP], then PUSH of element X is implemented as:
 - return stack[SP++]
 - stack[SP++] = X
 - stack[SP--] = X
 - stack[++SP] = X
- Which binary tree traversal corresponds to the following recursive code?


```
void traverse(noderef x)
{
  if (x==null)
    return;
  traverse(x.left);
  // process x here
  traverse(x.right);
}
```

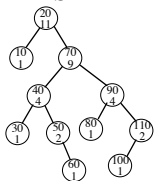
 - inorder
 - postorder
 - preorder
 - search for key x
- What is the worst-case time to perform MAXIMUM(L) for an ordered, doubly-linked list with n nodes?
 - $\Theta(1)$
 - $\Theta(\log n)$
 - $\Theta(n)$
 - $\Theta(n \log n)$
- Given a pointer to a node, the worst-case time to delete the node from a doubly-linked list with n nodes in ascending order is:
 - $\Theta(1)$
 - $\Theta(\log n)$
 - $\Theta(n \log n)$
 - $\Theta(n)$
- Which sort treats keys as several digits and uses a counting sort for each position?
 - counting
 - insertion
 - merge
 - radix
- The most accurate description of the time to perform a rotation in an unbalanced binary search tree with n keys and height h is:
 - $O(\log h)$
 - $O(h)$
 - $O(\log n)$
 - $O(1)$
- Subtree sizes are needed for which operation?
 - setting tombstones
 - successor
 - key rank
 - flattening
- In a binary search tree, which element does not have a successor?
 - any one of the leaves
 - the minimum
 - the maximum
 - the root
- Which of the following will not be true regarding the decision tree for HEAP-SORT for sorting n input values?
 - Every path from the root to a leaf will have $O(n \log n)$ decisions.
 - The height of the tree is $\Omega(n \log n)$.
 - There will be a path from the root to a leaf with $\Omega(n^2)$ decisions.
 - There will be $n!$ leaves.
- The worst-case number of comparisons for finding the k th largest of n keys using PARTITION is in which asymptotic set?
 - $\Theta(\log n)$
 - $\Theta(n)$
 - $\Theta(n \log n)$
 - $\Theta(n^2)$

Long Answer

- Twenty million positive integers in the range $0 \dots 999,999,999$ are to be sorted by LSD radix sort. Compare the performance for using radix $0 \dots 999$ and radix $0 \dots 9$. **Show your work.** (15 points)
- Show the result after PARTITION manipulates the following subarray. Be sure to **circle** the version of PARTITION you applied. (15 points)

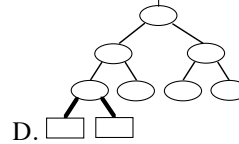
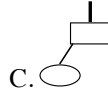
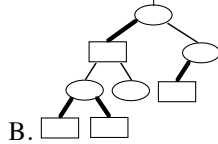
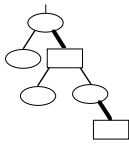
4	1	9	0	8	2	5	7	6	3
---	---	---	---	---	---	---	---	---	---

Version Applied: 1 2/Sedgewick
- Give the unbalanced binary search tree that results when the keys 50, 100, 70, 60, 90, 80, 120 are inserted, in the given order, into an initially empty tree. (15 points)
- Show the entire tree that results from a right rotation at 70. (15 points)

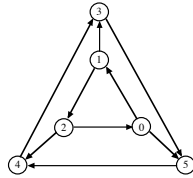


Multiple Choice. Write the letter of your answer to the LEFT of each problem. 2 points each

1. Which algorithm maintains multiple subtrees?
 A. Prim's B. Warshall's C. Dijkstra's. D. Kruskal's
2. Which of the following binary trees has an illegal red-black tree coloring?



3. The worst-case time for depth-first search is:
 A. $\theta(V \log E)$ B. $\theta(E \log V)$ C. $\theta(V \log V)$ D. $\theta(V + E)$
4. In Dijkstra's algorithm, the final shortest path distance from the source s to a vertex x is known when:
 A. some vertex y moves from T to S and there is an edge from y to x .
 B. x has its entry extracted from the heap.
 C. x is placed on the heap.
 D. x is read from the input file.
5. When a graph is dense, the best way to find a minimum spanning tree is:
 A. Floyd-Warshall algorithm B. Prim's algorithm using heap
 C. Prim's algorithm using T-table D. Warshall's algorithm
6. Suppose a directed graph has a path from vertex X to vertex Y , but no path from vertex Y to vertex X . The relationship between the discovery times is:
 A. $\text{discovery}(X) < \text{discovery}(Y)$ B. $\text{discovery}(X) > \text{discovery}(Y)$
 C. $\text{discovery}(X) = \text{discovery}(Y)$ D. could be either A. or B.
7. The worst-case time for the memoryless version of Dijkstra's algorithm is:
 A. $\theta(V^2 + E)$ B. $\theta(E \log V)$ C. $\theta(V \log V)$ D. $\theta(EV)$
8. The time for Warshall's algorithm for a directed graph with n vertices is in:
 A. $\Theta(n)$ B. $\Theta(n \log n)$ C. $\Theta(n^2)$ D. $\Theta(n^3)$
9. When using two breadth-first searches to find the diameter of a tree, the purpose of the first search is to find:
 A. all vertices that could be an end of a diameter. B. both ends of a diameter.
 C. one end of a diameter. D. the number of edges in the diameter.
10. During a breadth-first search, the status of a white vertex is:
 A. It has been completely processed. B. It is in the FIFO queue.
 C. It is in the priority queue. D. It is undiscovered.
11. A topological ordering of a directed graph may be computed by:
 A. Ordering the vertices by ascending discovery time after DFS
 B. Ordering the vertices by descending finish time after DFS
 C. Ordering the vertices by ascending finish time after DFS
 D. Ordering the vertices by descending discovery time after DFS
12. When finding the strongly connected components, the number of components is indicated by:
 A. The number of back edges found during the first depth-first search.
 B. The number of cross edges found during the second depth-first search.
 C. The number of times the vertex color table is scanned during the first depth-first search.
 D. The number of times the vertex color table is scanned during the second depth-first search.
13. What is the purpose of the first depth-first search when finding strongly connected components?
 A. To assure that two vertices, X and Y , with paths from X to Y but not from Y to X , are output in different components.
 B. To make sure that the input graph has no cycles.
 C. To assure that two vertices that are in the same cycle will be output in the same component
 D. To assure that two vertices, X and Y , with paths from X to Y but not from Y to X , are output in the same component.
14. The number of potential probe sequences when using linear probing with a table with m entries is:
 A. m B. $m + 1$ C. $m(m - 1)$ D. $m!$
15. What is the number of strongly connected components in this graph?



A. 1

B. 2

C. 3

D. 4

16. The following matrix was produced by Warshall's algorithm with successors. How many vertices are on the represented path from 3 to 3?

-1	3	3	3	3
-1	3	3	3	4
-1	1	1	1	4
-1	2	2	2	2
-1	-1	-1	-1	-1

A. 0

B. 1

C. 2

D. 3

17. Suppose that a directed graph is to be stored and then queries for the presence of various edges will be submitted. Which of the following worst-case time bounds for testing whether one edge is present is **incorrect**? (Vertices are conveniently labeled by numbers $0, 1, \dots, V - 1$.)

A. Compressed adjacency lists (ordered): $\Theta(\log V)$ B. Adjacency lists (ordered): $\Theta(\log V)$ C. Adjacency lists (unordered): $\Theta(V)$ D. Adjacency matrix: $\Theta(1)$

18. The main disadvantage of compressed adjacency lists is:

A. Directed graphs may not be represented

B. It is difficult to change the graph

C. They waste space

D. Undirected graphs may not be represented

19. Suppose there is exactly one path from vertex 7 to vertex 10 in a directed graph: $8 \rightarrow 7 \rightarrow 3 \rightarrow 5 \rightarrow 10$. During the scan of which column will Warshall's algorithm record the presence of this path?

A. 3

B. 5

C. 7

D. 8

E. 10

20. For a double hash table with $\alpha = 0.5$ (without deletions), the upper bound on the expected number of probes for unsuccessful search is:

A. 1.2

B. 2

C. 5

D. 10

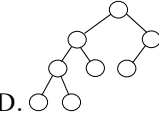
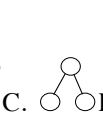
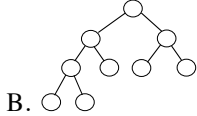
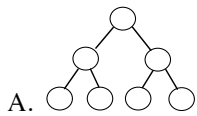
21. Using the values *never-used* (-1) and *recycled* (-2) are part of which data structure?

A. hashing with chaining B. open addressing

C. ordered linked list

D. unbalanced binary search tree

22. Which of the following binary trees has *exactly* one legal coloring as a red-black tree?



- Problems 23 and 24 refer to the following hash table whose keys are stored by double hashing using $h_1(\text{key}) = \text{key} \% 13$ and $h_2(\text{key}) = 1 + (\text{key} \% 12)$.

0	1	2	3	4	5	6	7	8	9	10	11	12
			120	186	187	162		122	110			194

23. 266 would be inserted into which slot of the given table?

A. 0

B. 1

C. 2

D. 7

E. 10

F. 11

24. 313 would be inserted into which slot of the given table? (266 has not been inserted)

A. 0

B. 1

C. 2

D. 7

E. 10

F. 11

25. Which edge is chosen in a phase of Kruskal's algorithm?

A. An edge of maximum-weight in a cycle (to be excluded)

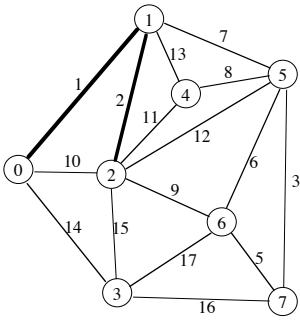
B. A minimum-weight edge that keeps the result free of cycles

C. A minimum-weight edge connecting T to S.

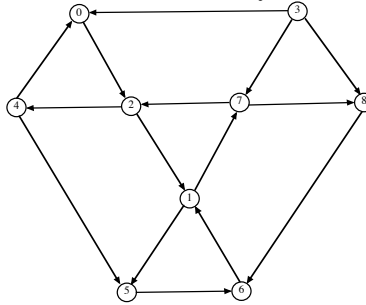
D. An edge that is on a shortest path from the source

Long Answer

1. What are the entries in the heap (for Prim's algorithm) before and after moving the next vertex and edge into the minimum spanning tree? **DO NOT COMPLETE THE ENTIRE MST!!!** Edges already in the MST are the thick ones. Edges currently not in the MST are the narrow ones. You do not need to show the binary tree for the heap ordering. 10 points.

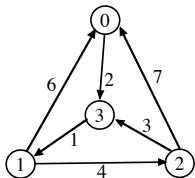


2. Perform depth-first search on the following graph, including start/finish times and edge types (T=tree, B=back, C=cross, F=forward.) Assume that the adjacency lists are **ordered**. Write your answer in the tables below. 10 points

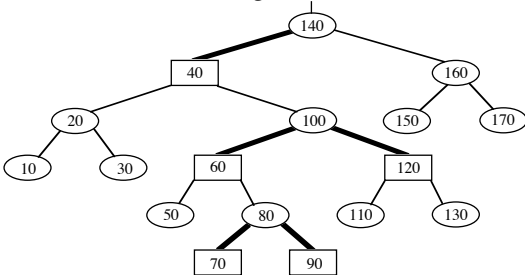


Vertex	Start	Finish	Edge	Type	Edge	Type
0	<u>1</u>	___	0 2	___	5 6	___
1	___	___	1 5	___	6 1	___
2	___	___	1 7	___	7 2	___
3	___	___	2 1	___	7 8	___
4	___	___	2 4	___	8 6	___
5	___	___	3 0	___		
6	___	___	3 7	___		
7	___	___	3 8	___		
8	___	___	4 0	___		
			4 5	___		

3. Demonstrate the Floyd-Warshall algorithm, **with successors**, for the following graph. The paths indicated in the final matrix must have **at least one** edge. You **are not** required to show the intermediate matrices. 10 points.



4. Insert 135 into the given red-black tree. Be sure to indicate the cases that you used. (10 points)



5. Show the **compressed** adjacency list representation for this graph. (Answers using conventional adjacency lists will receive no credit.) 10 points.

