This exam is **no book, no notes, no gadgets**. You have the full period (50 minutes). There are 23 questions, worth 56 total points. Marks will be curved so the median is B at least.

Name (Print):

*This exam is my own work. I understand it is governed by the Emory Honor Code.*

Signature:

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**Multiple Choice**: choose the best answer for each.

(2 pts) 1. We added random edges to a graph until it was connected. Which of these told us when to stop?
   - A. BFS
   - B. CC
   - C. DFS
   - D. SCC
   - E. UF

(2 pts) 2. In the particle system simulation, what kind of data structure stores the future events?
   - A. an array
   - B. some BST
   - C. hash table
   - D. a heap
   - E. UF

(2 pts) 3. In SymbolGraph (which reads *movies.txt*), what maps vertex names to numbers?
   - A. an array
   - B. some BST
   - C. hash table
   - D. a heap
   - E. UF

(2 pts) 4. In SymbolGraph, what data structure maps vertex numbers to names?
   - A. an array
   - B. some BST
   - C. hash table
   - D. a heap
   - E. UF

(2 pts) 5. Who invented our method for BST deletion?
   - A. Floyd
   - B. Hibbard
   - C. Knuth
   - D. Sedgewick
   - E. Tarjan

(2 pts) 6. Where does BFS keep track of the vertices it needs to visit next?
   - A. explicit stack
   - B. runtime stack
   - C. fifo queue
   - D. priority queue
   - E. marked array

(2 pts) 7. What DFS edge type cannot occur in the traversal of an undirected graph?
   - A. back
   - B. cross
   - C. forward
   - D. parallel
   - E. tree

(2 pts) 8. What DFS edge type cannot occur in the traversal of an acyclic digraph (DAG)?
   - A. back
   - B. cross
   - C. forward
   - D. parallel
   - E. tree

(2 pts) 9. Which is NOT found using DFS?
   - A. bridges
   - B. connected components
   - C. cycles
   - D. shortest paths
   - E. topological order

(2 pts) 10. Which red edge arrangements cannot occur during insertion in a left-leaning red-black tree?
   - Choose TWO of these:
   - A. $\nearrow$
   - B. $\nwarrow$
   - C. $\leftarrow$
   - D. $\rightarrow$
   - E. $\searrow$
Fill in the Blank: partial credit is sometimes possible.

(2 pts) 11. Suppose we store a binary heap in an array, with the root at index 1. If a node is at index \( j \), the right child of that node is at what index?

11. ______________

(2 pts) 12. After a full DFS traversal of a DAG, we can get a topological sort by listings its vertices in what order?

12. ______________

(2 pts) 13. What algorithm from the book could be made faster by running a DFS for just one vertex per SCC, as observed in class?

13. ______________

(2 pts) 14. Given a graph with \( V \) vertices and \( E \) edges, how much extra space (beyond the graph itself) is used by DFS? (Use big-Oh.)

14. ______________

(2 pts) 15. Sarnak and Tarjan designed a partially persistent version of what data structure?

15. ______________

(2 pts) 16. TopM computes the \( M \) largest of \( N \) input numbers using \( O(M) \) space, and how much time? (Use big-Oh.)

16. ______________

(2 pts) 17. The BST rank and select methods rely on what extra data field (beyond key, value, left, right), present in each node?

17. ______________

(2 pts) 18. The fail-fast TreeMap iterators check that what field (of the TreeMap) still has its expected value?

18. ______________

(2 pts) 19. Which hashing method allows deletion in worst-case time \( O(1) \)?

19. ______________

(2 pts) 20. We observe clustering in which hashing method?

20. ______________
Short Answer.

(6 pts) 21. Describe a situation where we need a family of hash functions (from which we can pick one at random), rather than just one fixed hash function.

(6 pts) 22. Consider digraph $H$ on the board. Assume its adjacency lists are in sorted order. Consider a DFS traversal of $H$ (so at the top level, we start a DFS at each unmarked vertex). Draw $H$, indicating the tree edges, and also the “pre-order” labels (in other words, write $\text{pre}[v]$ next to each $v$).

(4 pts) 23. Supposing $H$ is the reverse of $G$, and we are using Kosaraju’s algorithm to compute the SCC’s of $G$. In the second DFS traversal, in what order would the algorithm consider the vertices of $G$? (Write down the ordering.) Also, indicate the SCC’s of $G$ (just as subsets, you do not need to draw trees).