Student Name: ______________________ Student ID # ______________________

**OU Academic Integrity Pledge**

*On my honor I affirm that I have neither given nor received inappropriate aid in the completion of this exercise.*

Signature: ______________________ Date: ______________________

**Notes Regarding this Examination**

**Open Book(s)** You may consult any printed textbooks in your immediate possession during the course of this examination.

**Open Notes** You may consult any printed notes in your immediate possession during the course of this examination.

**No Electronic Devices Permitted** You may not use any electronic devices during the course of this examination, including but not limited to calculators, computers, and cellular phones. All electronic devices in the student's possession must be turned off and placed out of sight (for example, in the student's own pocket or backpack) for the duration of the examination.

**Violations** Copying another's work, or possession of electronic computing or communication devices in the testing area, is cheating and grounds for penalties in accordance with school policies.

Part I. Data Structures Concepts

1. (2 points) AVL trees have a lookup time roughly equal to that of which other data structure?
   - A. Hash Table
   - B. Unsorted Array
   - ***C. Sorted Array***
   - D. Linked List
   - E. None of the Above

2. (2 points) AVL trees have an *insertion* time (after lookup) roughly equal to that of which other data structure?
   - A. Hash Table
   - B. Unsorted Array
   - C. Sorted Array
   - D. Linked List
   - ***E. None of the Above***

3. (2 points) AVL trees have a *deletion* time (after lookup) roughly equal to that of which other data structure?
   - A. Hash Table
   - B. Unsorted Array
   - C. Sorted Array
   - D. Linked List
   - ***E. None of the Above***

4. (2 points) Which is true of full binary trees?
   - A. Every node has two child nodes
   - B. If you delete a node, the tree will be complete
   - C. If you delete a node, the tree will not be complete
   - D. If you delete a node, the tree will decrease in height
   - ***E. If you add a node, the tree will increase in height***

5. (2 points) Which is true of AVL trees?
   - A. They are complete binary trees
   - B. They are full, sorted binary trees
   - C. They adjust their height through rotations on every insertion
   - ***D. They never have a height imbalance greater than 2***
   - E. They keep track of the height of each node

6. (2 points) Which is true of AVL trees?
   - ***A. Adding a node may cause the tree to increase in height***
   - B. Adding a node will cause the tree to increase in height
   - C. Adding a node may cause the tree to decrease in height
   - D. Adding a node will cause the tree to decrease in height
   - E. None of the Above

Part II. Time and Space Complexity of Trees

7. (2 points) What is the time complexity for efficiently finding an arbitrary item in an arbitrary binary tree of $n$ nodes?

   ***A.*** $\Theta(n)$
   B. $\Theta(\log_2 n)$
   C. $\Theta(1)$
   D. $\Theta(n^2)$
   E. $\Theta(n \log_2 n)$

8. (2 points) What is the time complexity for efficiently finding an arbitrary item in an arbitrary binary *search* tree of $n$ nodes?

   ***A.*** $\Theta(n)$
   B. $\Theta(\log_2 n)$
   C. $\Theta(1)$
   D. $\Theta(n^2)$
   E. $\Theta(n \log_2 n)$

9. (2 points) What is the time complexity for efficiently finding an arbitrary item in an arbitrary *AVL* tree of $n$ nodes?

   A. $\Theta(n)$
   ***B.*** $\Theta(\log_2 n)$
   C. $\Theta(1)$
   D. $\Theta(n^2)$
   E. $\Theta(n \log_2 n)$

10. (2 points) What is the time complexity for efficiently deleting an arbitrary item in an arbitrary binary tree of $n$ nodes, once the items has been located?

   A. $\Theta(n)$
   ***B.*** $\Theta(\log_2 n)$
   C. $\Theta(1)$
   D. $\Theta(n^2)$
   E. $\Theta(n \log_2 n)$

11. (2 points) What is the time complexity for efficiently deleting an arbitrary item in an arbitrary binary *search* tree of $n$ nodes, once the item has been located?

   A. $\Theta(n)$
   ***B.*** $\Theta(\log_2 n)$
   C. $\Theta(1)$
   D. $\Theta(n^2)$
   E. $\Theta(n \log_2 n)$

12. (2 points) What is the time complexity for efficiently deleting an arbitrary item in an arbitrary *AVL* tree of $n$ nodes, once the item has been located?

   A. $\Theta(n)$
   ***B.*** $\Theta(\log_2 n)$
   C. $\Theta(1)$
   D. $\Theta(n^2)$
   E. $\Theta(n \log_2 n)$

13. (2 points) What is the space complexity for efficiently storing $n$ items in a binary tree?
    - ***A.*** $\Theta(n)$
    - B. $\Theta(\log_2 n)$
    - C. $\Theta(1)$
    - D. $\Theta(n^2)$
    - E. $\Theta(n \log_2 n)$

14. (2 points) What is the space complexity for efficiently storing $n$ items in a binary *search* tree?
    - ***A.*** $\Theta(n)$
    - B. $\Theta(\log_2 n)$
    - C. $\Theta(1)$
    - D. $\Theta(n^2)$
    - E. $\Theta(n \log_2 n)$

15. (2 points) What is the space complexity for efficiently storing $n$ items in an *AVL* tree?
    - ***A.*** $\Theta(n)$
    - B. $\Theta(\log_2 n)$
    - C. $\Theta(1)$
    - D. $\Theta(n^2)$
    - E. $\Theta(n \log_2 n)$

16. (2 points) What is the maximum height for an arbitrary binary tree of $n$ items?
    - ***A.*** $\Theta(n)$
    - B. $\Theta(\log_2 n)$
    - C. $\Theta(1)$
    - D. $\Theta(n^2)$
    - E. $\Theta(n \log_2 n)$

17. (2 points) What is the maximum height for an arbitrary binary *search* tree of $n$ items?
    - ***A.*** $\Theta(n)$
    - B. $\Theta(\log_2 n)$
    - C. $\Theta(1)$
    - D. $\Theta(n^2)$
    - E. $\Theta(n \log_2 n)$

18. (2 points) What is the maximum height for an arbitrary *AVL* tree of $n$ items?
    - A. $\Theta(n)$
    - ***B.*** $\Theta(\log_2 n)$
    - C. $\Theta(1)$
    - D. $\Theta(n^2)$
    - E. $\Theta(n \log_2 n)$

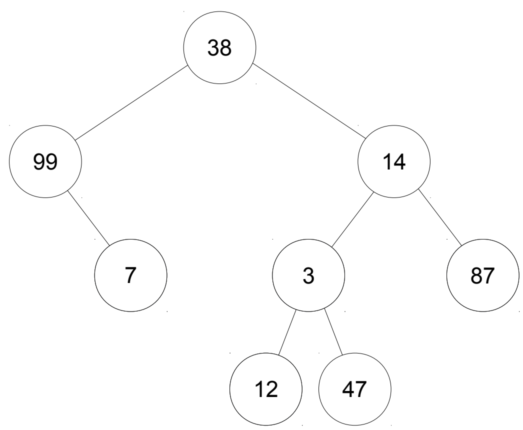
Part III. AVL Trees

19. (2 points) Which imbalance can be corrected with a single right rotation (aka "zig") operation?
    - ***A. Outside left heavy (aka left-left violation)***
    - B. Inside left heavy (aka left-right violation)
    - C. Inside right heavy (aka right-left violation)
    - D. Outside right heavy (aka right-right violation)
    - E. None of the Above

20. (2 points) If an interior node is deleted, with which should it be replaced?
    - A. Its parent (if one exists)
    - B. Its right child (if one exists)
    - C. Its left child (if one exists)
    - ***D. Its in-order successor (if one exists)***
    - E. Its post-order successor (if one exists)

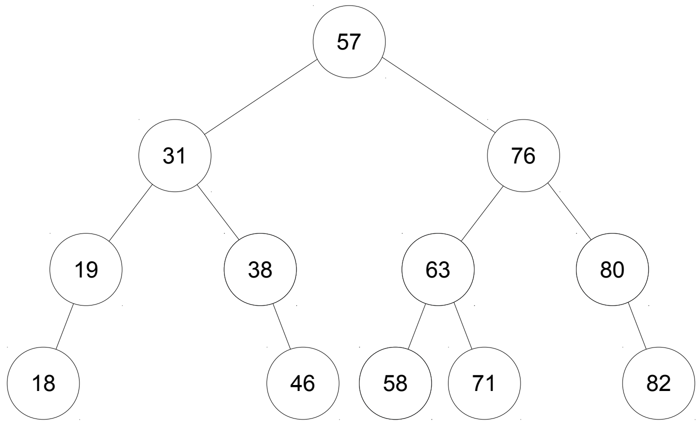
Exam continues with short answer questions.

**Short Answer Question 1:** Tree Traversal (5 points)




Show the pre-order traversal of the above binary tree.

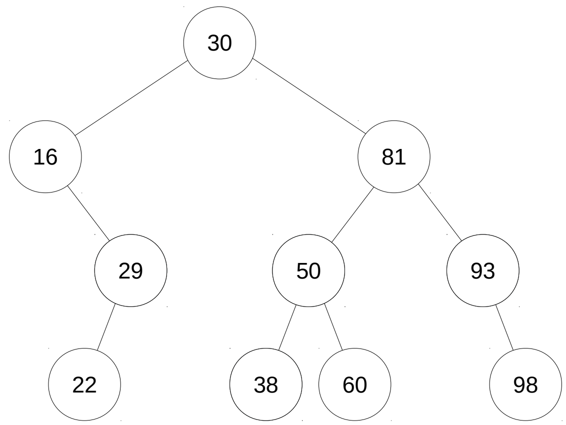
**Short Answer Question 2:** Binary Search Trees (10 points)




A. **Explain** how many key comparisons are necessary to perform a search for the key 63 in the tree above.

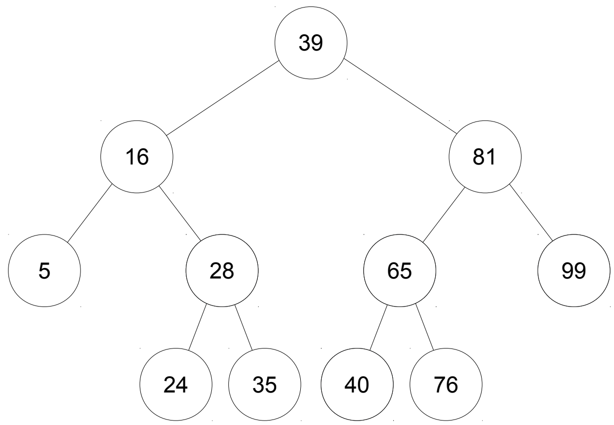
B. **Explain** how many key comparisons are necessary to perform a search for the key 30 in the tree above.

**Short Answer Question 3:** Self-Modifying Search Trees (10 points)




**Explain** the result of performing a zagzig operation on the node with key 16 in the tree above.

**Short Answer Question 4:** AVL Trees (15 points)




**Explain** the result of deleting the node with key 81 in the above tree.

**Short Answer Question 5:** Ethics (20 points)

"This is not good. Really not good."

Plamen is looking at the website that the National Organization for Tracking Contagious Disease Conveyance (NOTCDC) has set up to track the spread of Alobe, a deadly hemorrhagic disease.

"What is it?" inquires a visibly distressed Dimitar, "Is Alobe spreading near here?"

"Huh? Oh, uh, no. Nothing like that. But check out this URL." Plamen points at the screen.

"I don't get it," responds Dimitar, "what am I looking at?"

Plamen explains. "See, this part here is clearly just a query to an SQL database or something along those lines. It was generated by the button I clicked on the NOTCDC website."

"Yeah? And?"

"And, well, I hope I'm wrong but I've read about stuff like this. Some brainless IT drone will be told to make certain data publicly available, so they put their whole database on their web server and make a web interface that generates URLs with embedded queries that can be tossed to the database. Whatever the database responds is displayed. The problem is that if someone can guess the field names in the database, they can generate their own queries and ask for data that was never meant to go public."

"Not good."

"Yeah, tell me about it. Someone might be able to find out the names and addresses of everyone with Alobe, or the names and addresses of everyone who had contact with everyone with Alobe. And the other not good thing is that with the right URL, someone could even *change* the data in the database."

"Are you sure?"

"No," answers Plamen as he enters a new URL into his web browser, "but someone needs to find out and I guess that someone is me."

A. Find at least one computer crimes law that is relevant to this scenario. List the name of the law and *explain* why you think it is relevant.

B. Say whether you think Plamen abided by (that is, followed) the law you listed and *explain* how you came to that conclusion.

C. Give one likely motivation for Plamen's action and *explain* how you concluded that was a likely motivation.

D. List one ethical-decision-making problem (interfering factor) that is likely to have contributed to at least one of Plamen's decisions and *explain* how you concluded that was a likely problem.

E. List one ethical-decision-making strategy that Plamen could employ to improve his ethical decision making and *explain* how he might employ that strategy in this situation.