Theory Questions

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1. Compare and contrast arrays vs linked lists in terms of memory usage, access time, and insertion/deletion operations.

Aspect	**Array**	**Linked List**
Memory Usage	Fixed size; may waste or run out of space	Dynamic size; memory allocated as needed
Access Time	$O(1)$ for random access via indexing	$O(n)$ for access; must traverse nodes
Insertion (Middle)	$O(n)$; requires shifting elements	$O(1)$ if position is known (pointer update)
Deletion (Middle)	$O(n)$; requires shifting elements	$O(1)$ if position is known (pointer update)

Table 1: Comparison of Arrays vs Linked Lists

2. Explain the trade-offs between different collision resolution techniques in hash tables.

Separate Chaining: Uses linked lists to store multiple items in one bucket. Easy to implement, but uses extra memory and becomes slow if too many items collide. It works well even when the table gets full. Insertion is always $O(1)$ if added at the head. Lookup time increases if many elements hash to the same index.

Open Addressing: Finds another spot in the table when a collision happens. Doesn't need extra memory, but performance drops as the table fills. Harder to implement due to probing logic. Resizing and rehashing are more complex in open addressing.

3. When would you choose Quick Sort over Merge Sort, and vice versa?

Quick Sort: Use when working with arrays and low memory. It is fast in practice but not stable. Avoid if worst-case performance is a concern.

Merge Sort: Use when working with linked lists or when stable sorting is needed. It is always $O(n \log n)$ but uses more memory for arrays.

4. What makes a sorting algorithm "stable" and why does it matter?

A sorting algorithm is called **stable** if it keeps the original order of equal elements. This is important when sorting based on one field but keeping the order of other fields. Stability is useful in multi-level sorting (like by age then by name). Stable sorts make grouped data easier to read and understand. Algorithms like Merge Sort and Insertion Sort are stable by design.