Assignment 2

Due Date: April 18, 2025, at 11:59 pm
10% of the final grade

NAME: _____

UPI: _____

ID: _____

Please ensure that you fill in your name, UPI, and ID above.

It's best to answer Q2 after completing your Week 5 lab, and Q3 after completing your Week 6 lab.

Completely fill the circles as shown: ○○●○

Q1 [**3 marks**] Assume that each block is 1KB, and the buffer pool is 1MB.

1. [**1 mark**] What is the maximum file size that can be sorted using external memory sorting in two passes? Recall that the first pass follows the create-runs step.

   ○ a. 1TB
   ○ b. 10GB
   ○ c. 1GB
   ○ d. 100MB
   ○ e. None of the above

2. [**1 mark**] Consider a 10GB relation and construct a B+ tree for the relation using external memory sorting. Assume that all leaf nodes (each stored in a block) are full and that all internal nodes reside in the main memory. What is the total number of I/Os required to construct the B+ tree? Note:

   i. The leaf nodes of the B+ tree are **stored** on disk.
   ii. Constructing the first-level index of the B+ tree requires reading the sorted file of the relation once.

   ○ a. 70M
   ○ b. 80M
   ○ c. 90M
   ○ d. 100M
   ○ e. None of the above

3. [**1 mark**] A colleague is preparing to interview a candidate and would like to assess their knowledge of indexing. The colleague has compiled a list of statements and requests that you identify which ones are true. Please select all the correct statements.

   ○ Write-optimized indices can significantly reduce the cost of inserts, and to a lesser extent, of updates, as compared to B+trees. On the other hand, the index lookup cost can be significantly higher for write-optimized indices as compared to B+trees.
   ○ NULL values can be easily treated because they represent the absence of a value, making it straightforward to handle them without requiring special attention.
   ○ Bloom filters can eliminate unnecessary disk I/Os.
   ○ Bloom filters are effective for exact-match (or lookup) queries.
   ○ None of the above

Q2 **[4 marks]** Consider the B^+-tree shown in Figure 1 with two levels of nodes. Each leaf node occupies a block, as does each internal node. Each block can hold up to 3 tuples, or alternatively, it can function as an internal node with a fanout of 5. Answer the following questions.

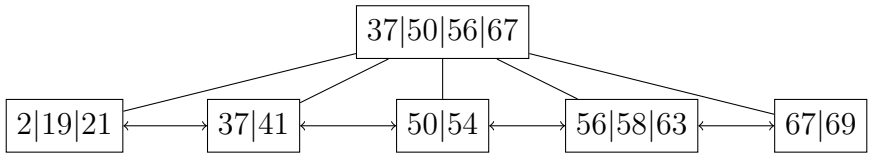
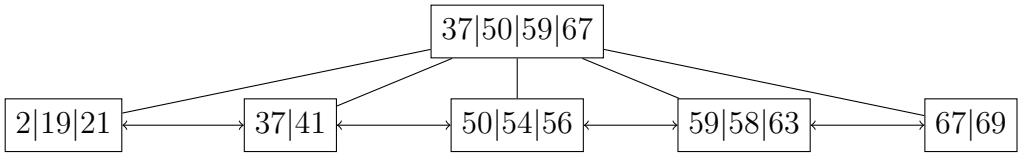


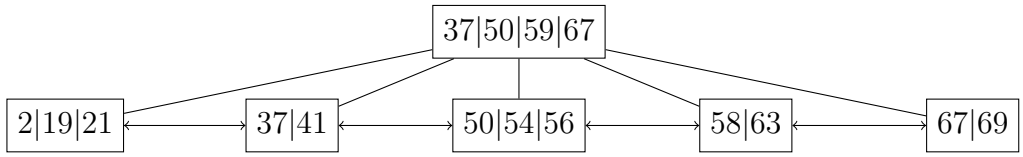
Figure 1: B^+-tree

1. **[1 mark]** Insert 59 to the B^+ tree of Figure 1. Select the resulting tree.

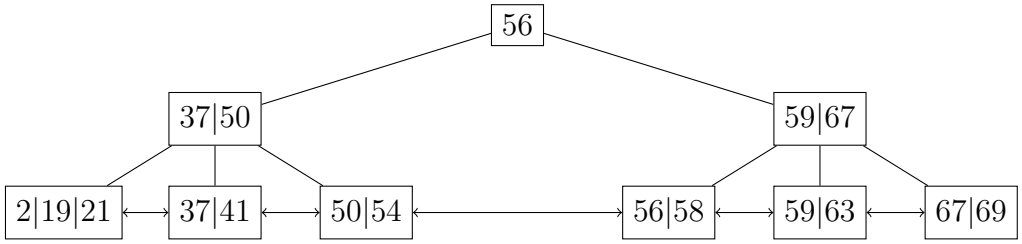
○ a.



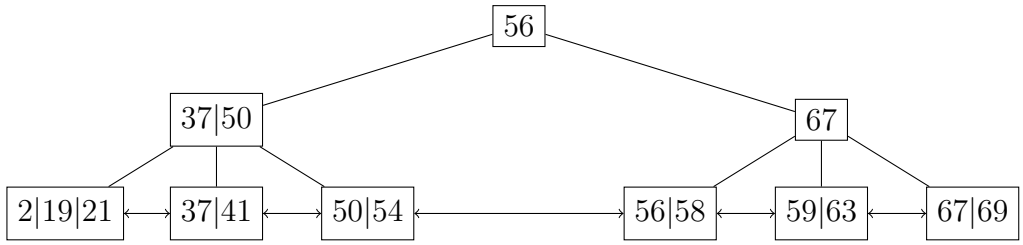
○ b.



○ c.



○ d.



2. **[1 mark]** After inserting 59 to Figure 1, how many I/Os are need to find all the tuples with keys in an open range of $(35, 57)$? Assume the root is stored in the main memory and exclude the I/O cost of reporting the output.

○ a. 2
○ c. 3
○ b. 4
○ d. 5

3. **[1 mark]** During the sequential insertion of the values 59, 4, 8, 1, 5, and 7 into the B+ Tree shown in Figure 1, how many nodes were split?

○ a. 2
○ b. 3
○ c. 4
○ d. 5

4. **[1 mark]** How many tuples a B^+tree of 4 levels can store at most under current parameters?

○ a. 75
○ b. 375
○ c. 1875
○ d. 150

Q3 [**3 marks**] Consider an extendible hashing structure such that:

- Each bucket can hold up to three records.
- The hashing function uses the highest g bits (left bits are high) of the hashing value, where g is the global depth.
- A new extendible hashing structure is initialized with g = 0 and one empty bucket.
- If multiple keys are provided in a question, assume they are inserted one after the other from left to right.
- Records with duplicate keys will be retained without deduplication.

Key	Hashing value	Key	Hashing value
7	000	18	100
20	110	25	100
37	010	44	010
49	000	50	001
51	010	69	110

1. [**1 mark**] After inserting 50, 44, 25, 20, 37, what are the local depth of the bucket containing 25 and the global depth, respectively?

- ○ a. 25 (depth 0). The global depth is 1.
- ○ b. 25 (depth 1). The global depth is 1.
- ○ c. 25 (depth 2). The global depth is 1.
- ○ d. 25 (depth 1). The global depth is 2.

2. [**1 mark**] Starting from the results of question Q3.1, insert 7. What are the local depths of the buckets for each key?

- ○ a. 7 (depth 2), 20 (depth 1), 25 (depth 1), 37 (depth 2).
- ○ b. 7 (depth 2), 20 (depth 2), 25 (depth 1), 37 (depth 2).
- ○ c. 7 (depth 2), 20 (depth 1), 25 (depth 2), 37 (depth 2).
- ○ d. 7 (depth 1), 20 (depth 1), 25 (depth 1), 37 (depth 2).

3. [**1 mark**] Starting from the results of question Q3.2, insert 51, 49, 18, 69, 37. What are the local depths of the buckets for each key? What is the global depth?

- ○ a. 20 (depth 2), 25 (depth 2), 37 (depth 3), 50 (depth 2). Global depth: 3.
- ○ b. 20 (depth 2), 25 (depth 2), 37 (depth 3), 50 (depth 3). Global depth: 3.
- ○ c. 20 (depth 2), 25 (depth 2), 37 (depth 2), 50 (depth 2). Global depth: 2.
- ○ d. 20 (depth 2), 25 (depth 1), 37 (depth 3), 50 (depth 2). Global depth: 3.