Quiz #2

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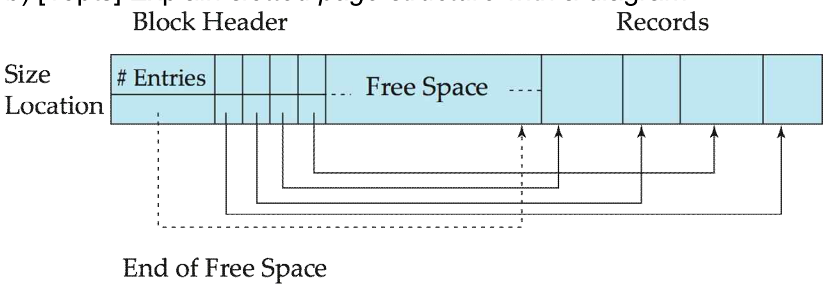
1. [5pts] Explain two components of the disk *access time*.
   Seek time – time it takes to reposition the arm over the correct track
   Rotational latency – time it takes for the sector to be accessed to appear under the head

2. [5pts] Describe two reasons why RAID systems are used.
   To provide a view of a single disk of
   - high capacity and high speed by using multiple disks in parallel
   - high reliability by storing data redundantly, so that data can be recovered even if a disk fails

3. a) [5pts] What would be the problems if *byte string representation* or *fixed length representation* is used for variable-length records?
   Byte string representation – difficulty with deletion / growth
   Fixed length representation – waste of unused space in shorter records, filled with a null or end-of-record symbol

b) [10pts] Explain *slotted page structure* with a diagram.



4. [5pts] Describe the pros and cons of *sequential file organization*.
  Pros: suitable for applications that require sequential processing of the entire file
  Cons: insertion/deletion overhead, need to reorganize periodically

5. a) [5pts] Why does hash bucket *skew* occur?
  - Multiple records have same search-key value
  - Chosen hash function produces non-uniform distribution of key values

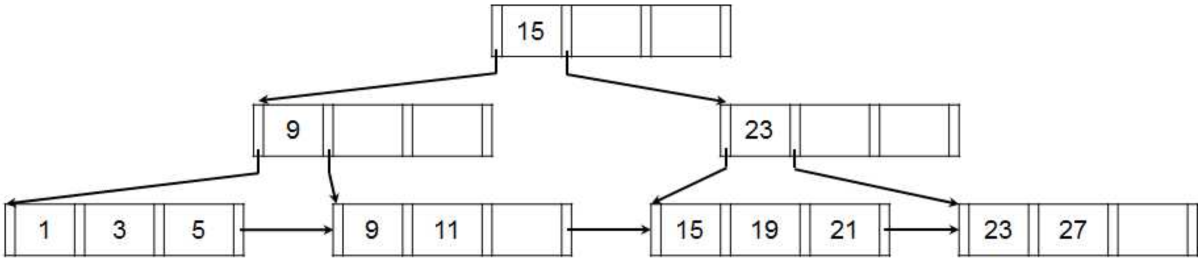
b) [5pts] What is the deficiencies of *static hashing*?
  - If initial number of buckets is too small, and file grows, performance will degrade due to too much overflows.
  - If initial number of buckets is too large, or database shinks, a significant amount of space will be wasted.

6. [10pts] Describe the pros and cons of using *balanced tree*(B-tree and its variants) and *binary tree* as an index in database systems.
  - Balanced tree(B-tree and its variants)
  Pros: Average query performance is guaranteed because every path from the root to a leaf of the tree has the same length.
  Overall reorganization is not required because it maintains the balanced form.
  Cons: Additional performance overhead and implementation complexity for balancing is imposed on insertion and deletion.
  - Binary tree
  Pros: Insertion and deletion is straightforward.
  Cons: Query performance is unpredictable if the tree is unbalanced.
  Overall reorganization may be required for performance.

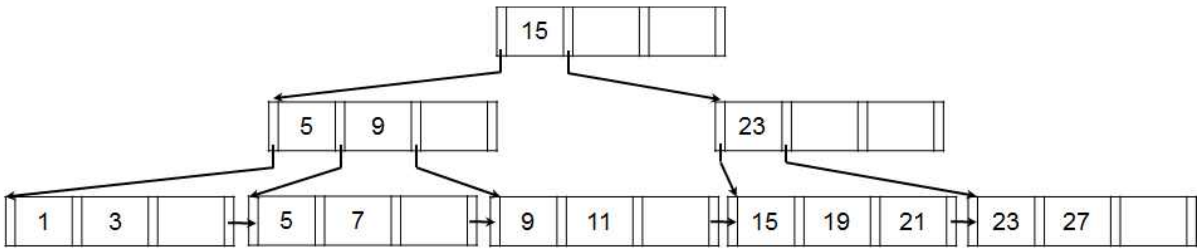
7. [5pts: 1pt each / 0pt for no answer / -1pt for a wrong answer] Fill in the blanks.

A B+-tree is a rooted tree satisfying the following properties.
- Each branch node (that is not a root or a leaf) has between __4__ and 7 *children*.
- A leaf node has between __3__ and __6__ *values*.
- If the root is not a leaf, it has at least __2__ *children*.
- If the root is a leaf, it can have between 0 and __6__ *values*.

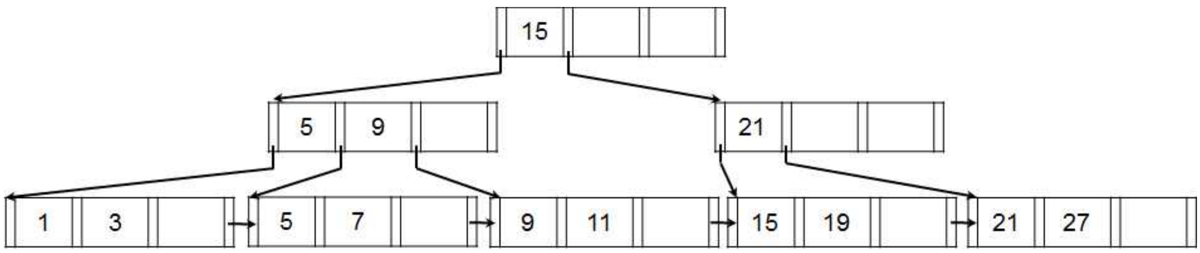
8. For the following B+-tree, show the form of the tree after each of the following series of operations.



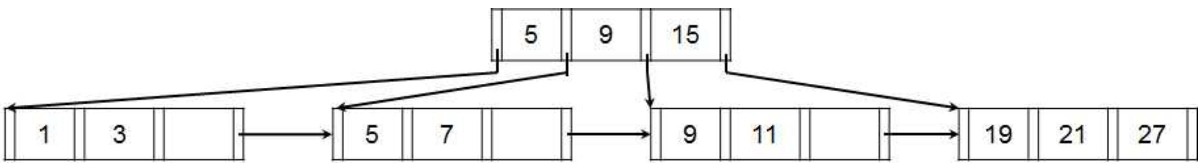
a) [5pts] Insert 7.



b) [5pts] Delete 23.



c) [5pts] Delete 15.



9. [5pts] Suppose you decide to use a *primary index* or *secondary index*, to select from a relation with an *equality condition*. The selection condition can be on a *key* or a *non-key* attribute. Does the choice of index affect the selection cost? Justify your answer.
Both index result in the same cost for the selection on a key attribute.
However, cost may differ for the selection on a non-key attribute if it retrieves multiple matching records which may be on a different block.

10. [10pts] Suppose you need to sort a relation of 40 gigabytes, with 4 kilobyte blocks, using a memory size of 40 megabytes. Suppose the cost of a seek is 5 milliseconds, while the disk transfer rate is 40 megabytes per second. Find the cost of sorting the relation, in seconds, with $b_b = 1$ and $b_b = 100$.

b_r = 40GB / 4KB = 10,000,000 blocks
M = 40MB / 4KB = 10,000 blocks
The initial number of runs = (b_r / M) = 1,000
The number of merge passes required = $\lceil \log_{M-1}(b_r / M) \rceil = \lceil \log_{9999} 1000 \rceil = 1$
Block transfers = $b_r(2*1 + 1)$ (merging) = 30,000,000 blocks
Seeks = $2\lceil b_r / M \rceil + \lceil b_r / b_b \rceil (2*1 - 1)$
$\therefore$ if b_b = 1, 2000 + 10,000,000 = 10,002,000 seeks
b_b = 100, 2000 + 100,000 = 102,000 seeks
Total sorting cost in seconds = (# of block transfers) * 4KB / 40MB + (# of seeks) * 5/1000
$\therefore$ if b_b = 1, 30,000,000 * 4KB / 40MB + 10,002,000 * 5/1000 = 3000 + 50010 = 53010 sec.
b_b = 100, 30,000,000 * 4KB / 40MB + 102,000 * 5/1000 = 3000 + 510 = 3510 sec.

11. Let relations r and s have the following properties: r has 10,000 tuples, s has 27,000 tuples, 25 tuples of r fit on one block, and 30 tuples of s fit on one block. Estimate the number of block transfers and seeks required in the *worst case*, using each of the following join strategies for the natural join between r and s.

b_r = 10,000 / 25 = 400
b_s = 27,000 / 30 = 900

a) [5pts] Nested-loop join, with r as the outer relation.
Block transfers = $n_r * b_s + b_r$ = 10,000 * 900 + 400 = 9,000,400 blocks
Seeks = $n_r + b_r$ = 10,000 + 400 = 10,400 seeks
b) [5pts] Block nested-loop join, with r as the outer relation.
Block transfers = $b_r * b_s + b_r$ = 400 * 900 + 400 = 360,400 blocks
Seeks = 2 * b_r = 2 * 400 = 800 seeks
c) [5pts] Hash join, using 20 buffers for the input and each 4 output partitions.
$b_b = 20$, $n_h = 4$
Block transfers = $3(b_r + b_s) + 4 * n_h$ = 3(400 + 900) + 4 * 4 = 3916 blocks
Seeks = $2(\lceil b_r / b_b \rceil + \lceil b_s / b_b \rceil) + 2 * n_h$ = 2(20 + 45) + 2 * 4 = 138 seeks