KARTHIK MAHESH

Name

A20383027

CWID

Quiz
1

Sept 24th, 2018
Due Oct 2nd, 11:59pm

Quiz 1: CS525 - Advanced Database Organization

Please leave this empty! 1.1 [ ] 1.2 [ ] 1.3 [ ] 1.4 [ ] Sum [ ]

Instructions

- **You have to hand in the assignment using your blackboard**
- **This is an individual and not a group assignment**
- Multiple choice questions are graded in the following way: You get points for correct answers and points subtracted for wrong answers. The minimum points for each questions is **0**. For example, assume there is a multiple choice question with 6 answers - each may be correct or incorrect - and each answer gives 1 point. If you answer 3 questions correct and 3 incorrect you get 0 points. If you answer 4 questions correct and 2 incorrect you get 2 points. . . .
- For your convenience the number of points for each part and questions are shown in parenthesis.
- There are 4 parts in this quiz

  1.SQL

  2.Relational Algebra

  3.Index Structures

  4.Result Size Estimation

Part 1.1 SQL (Total: 31 + 10 bonus points Points)

Consider the following political party schema and example instance.The example data should not be used to formulate queries. SQL statements that you write should return the correct result for every possible instance of the schema!

party

pName	leaning	established	endowment
JDF	middle right	1950	6,000,000
LKE	middle left	1951	5,500,000
HHH	far right	2010	2,300,000
GGK	middle	1980	10,000,000

member

name	party	since
Peter	JDF	2014
Bob	JDF	2014
Alice	JDF	2011
Alice	GGK	1990

positions

name	pos	year	salary
Alice	Governor of Alaska	2017	100,000
Alice	Vice President	2018	200,000
Bob	Secretary of State	2016	150,000

donations

pName	year	donor	amount
JDF	2017	Walmart	20,000,000
HHH	2018	Koch	40,000,000

Hints:

- Attributes with black background are the primary key attributes of a relation
- Attribute party of relation member is a foreign keys to relation party.
- Attribute pName of relation donations is a foreign key to relation party.

Question 1.1.1 (2 Points)

Write an SQL query that returns for each party the total amount of donation dollars per year as a rolling sum, i.e., the output for 2016 will be the sum of all of the donations made in up to and including year 20

```
SELECT distinct pName, year, sum(amount)
    OVER(PARTITION BY pName ORDER BY
    year ASC) as TotalDonations
FROM donations;
```

Question 1.1.2 (4 Points)

For each political leaning of parties (attribute leaning), return the names of the three donors which have donated the largest total donation (sum of donated dollars) to parties with this leaning.

```
WITH Total as (
SELECT leaning, donor, sum(amount)
 as Total1, row_number() over (partion by
  leaning, pName order by leaning,
   sum(amount) desc) as total2
FROM party natural join donations
GROUP BY leaning, donor)
 SELECT leaning, Total1
 FROM Total WHERE Total2 <24;
```

Question 1.1.3 (4 Points)

Write a query that calculates the average increase of salaries over positions over the years. That is for year, you have to compute the average factor by which the average salaries of positions have increased (or decreased) compared to the previous year. For instance, assuming we have only two positions *A* and *B* and in 2014 the average salary for position *A* is 20000 and in 2015 it is 40000, then the average pay for this position has increased by a factor of **2.0**.

```
With ~~pcount as~~ avgsal as(
SELECT pos, year, avg(salary) as avg
FROM positions GROUP BY pos, year
ORDER BY year)
SELECT pos, max(avg)/min(avg)
      as avgInc
FROM avgsal
GROUP BY pos;
```

Question 1.1.4 (5 Points)

Write an SQL query that returns positions (attribute pos) which have been held by some members of every party. That is, for each party we can find a member that has held the position.

```
With pcount as (
select count(pName) as total FROM party),
 ppcount as (
SELECT distinct party, pos
FROM member natural join positions
ORDER BY pos),
TotalPos as(
 SELECT pos, total as TotPos
 FROM pcount, ppcount
 GROUP BY pos
 HAVING count(pos) = total)
 SELECT pos
 FROM TotalPos;
```

Question 1.1.5 (2 Points)

Write an SQL Query that returns party members (their name) that have not have held any positions with a salary larger than $200,000.

```
SELECT name
FROM positions
WHERE salary <= 200,000
and name not in (
 SELECT name
 FROM positions
 WHERE salary > 200000);
```

Question 1.1.6 (2 Points)

Write an SQL query that returns the names of donors that have donated more than 50,000,000 in total.

```
SELECT donor, sum(amount) as Total
FROM donations
GROUP BY donor
HAVING Total > 50000000;
```

Question 1.1.7 (5 Points)

Write an SQL query that returns parties whose members have each hold at least one position.

```
SELECT pName FROM party
WHERE pName NOT IN (SELECT party
FROM member WHERE name in
(SELECT name FROM member
WHERE name NOT IN (SELECT name
FROM positions)) UNION
SELECT pName FROM (SELECT * FROM party P
LEFT OUTER JOIN member m on
(P.pName = m.party)) as PM
WHERE PM.name is NULL);
```

Question 1.1.8 (4 Points)

Write an SQL query that returns pairs of persons (party members) that are members of the same set of parties, e.g., Peter and Alice are both members of JDF, but Alice is also a member of GGK which Bob is not. Thus, the pair (Alice,Bob) should not be returned. Ensure that a pair of users is only returned once (e.g., do not both return (Peter,Bob) and (Bob,Alice)).

```
WITH uqname as (
SELECT name, party FROM member
GROUP BY name
HAVING count(name) = 1)
SELECT distinct a.name, b.name
FROM uqname a, uqname b
WHERE a.party = b.party and
      a.name < b.name;
```

Question 1.1.9 (4 Points)

Write a query that returns for each party and each year, the total amount of donations (dollar amount) the party has received in that year plus the two previous years. For instance, the result for a party in 2014 should include all donations made in 2012-2014 to that party.

```
SELECT pName PN, year as YR , sum(amount)
+( SELECT COALESCE (sum(amount), 0)
FROM donations
WHERE pName = PN and
      ( year = YR-1 or year = YR-2))
      as Total
FROM donations
GROUP BY pName, year
ORDER BY year, pName;
```

Question 1.1.10 Optional Bonus Question (10 Bonus Points)

Let's prove that SQL with recursion and arithmetic expressions is turing complete. To do that we are going to write a simulator for turing machines as a recursive SQL query. Recall that a turing machine is a tuple $(Q, \Gamma, b, \Sigma, q_0, F, \delta)$ where Q is a set of states, Γ is tape alphabet, $b \in \Gamma$ *ttamma* is the "blank" symbol, $\Sigma \subseteq \Gamma$ is the input alphabet, $q_0 \in Q$ is the initial state, $F \subseteq \Gamma$ is the set of final states, and $\delta : (Q \setminus F) \times \Gamma \rightarrow Q \times \Gamma \times \{L, R\}$ is the transition function. The state of a turing machine is stored on an infinite tape consisting of cells indexed by position. Each position of the tape stores a symbol from Γ. The initial state of the tape is the input to the turing machine. Only finitely many cells on the initial tape state may be non-blank (unequal to b). The turing machine starts in state q_0 at position **0** of the tape. In each step of its computation it reads the symbol under the current position of the tape and applies δ taking its current state and the symbol read from the tape as input. The result of δ is the new state for the next state, the symbol to be written to the tape at the current position, and the direction to move on the tape (if L then we update $pos = pos - 1$ and $pos = pos + 1$ otherwise). The computation of the turing machine stops once the computation reaches a final state q_f, i.e., a state in the set F.

We encode the turing machine and its tape using the following schema:

- states(q) - this relation stores the states of the turing machine, i.e., it encodes Q
- final(q) - this relation stores F
- We denote the start state by the string "q0".
- delta(qin, sin, qnew, sout, dir) - This relation encodes δ. If $\delta((q, s)) = (q', s', d)$ then this would be encoded as a tuple (q,s,q',s',d).
- tape(pos,sym) - This relation stores the symbol stored at each position of the initial configuration of the tape (the input). Positions that store the blank symbol are omitted from the relation.
- For simplicity assume that the blank symbol is the character *'b'* and any symbol from Γ can be encoded as a single character

Write a singlerecursiveSQL query that simulates the turing machine. The output of the query should be the final configuration of the tape once the machine reaches one of the final states from F (if the machine halts on this particular input). An example input database and result (tape state) is shown below.

states

q
q0
q1
q2

final

q
q2

delta

qin	sin	qnew	sout	dir
q0	0	q1	1	R
q0	1	q2	1	R
q0	b	q2	b	R
q1	0	q1	1	R
q1	1	q2	1	R
q1	b	q2	b	R

tape

pos	sym
0	0
1	0
2	0
3	1

result

pos	sym
0	1
1	1
2	1
3	1

Part 1.2 Relational Algebra (Total: 29 Points)

Question 1.2.1 Relational Algebra (2 Points)

Write a relational (bag semantics) algebra expression over the schema from the SQL part (part 1) that returns the names of parties which are *far right*, were established before 1960, and have an endowment that is larger than 2,000,000.

$\Pi_{pName}(\sigma_{leaning = \text{'far right'} \text{ AND } established < 1960 \text{ AND } endowment > 2000000}(party))$

Question 1.2.2 Relational Algebra (4 Points)

Write a relational (bag semantics) algebra expression over the schema from the SQL part (part 1) that returns parties that have gotten more than 3 donations.

$\Pi_{pName}(\sigma_{count(*) > 3}(pName\, \alpha\, count(*)(Donations)))$

Question 1.2.3 Relational Algebra (4 Points)

Write a relational (bag semantics) algebra expression over the schema from the SQL part (part 1) that returns parties that have no members and have not gotten any donations.

$q_1 \leftarrow \Pi_{pName}(party) - \Pi_{party}(member)$

$q_2 \leftarrow \Pi_{pName}(party) - \Pi_{pname}(donations)$

$q \leftarrow q_1 \cap q_2$

Question 1.2.4 SQL → Relational Algebra (5 Points)

Translate the SQL query from Question 1.1.1 into relational algebra (bag semantics).

$\rho_{Name,\ year\ as\ YR}\ \gamma_{sum(amount)}\ (\sigma_{year \leq YR}(donations))$

Question 1.2.5 SQL → Relational Algebra (5 Points)

Translate the SQL query from question 1.1.2 into relational algebra (bag semantics).

$q_1 \leftarrow {}_{leaning,\ donor}\gamma_{sum(amount) \rightarrow Total,\ row\_number \rightarrow a}\ (party \bowtie donor)$

$q_2 \leftarrow \Pi_{leaning,\ donor,\ Total}\ (\sigma_{a > 4}(q_1))$

Question 1.2.6 SQL → Relational Algebra (5 Points)

Translate the SQL query from question 1.1.3 into relational algebra (bag semantics).

$q_1 \leftarrow {}_{(pos,\ year)}\gamma_{avg(salary)}\ (positions)$

$\cdot\ {}_{pos}\gamma_{max(avg)/min(avg)}\ (q_1)$

Question 1.2.7 Equivalences (4 Points)

Consider the following relation schemas (primary key attributes are underlined):

$R(\underline{A}, B)$, $S(\underline{B}, C)$, $T(\underline{C}, D)$, $U(\underline{E}, F, tt)$.

Furthermore, assume that $S.B$ is a foreign key to R and $T.C$ is a foreign key to S. Check equivalences that are correct under **set semantics**. For example $R \bowtie R$ should be checked, whereas $R \bowtie S$ should not be checked.

- ☐ $R - (S - R) \equiv R - (R - S)$
- ■ $R - (R - S) \equiv S - (S - R)$
- ☐ ${}_{G}\alpha_{count(\square)}(U) \equiv {}_{G}\alpha_{sum(c)}({}_{F,G}\alpha_{count(\square)\to c}(U))$
- ☐ $\pi_C(S \bowtie R) \equiv \pi_C(S)$
- ■ $R \div S \equiv R - (\pi_{A,B}(R \bowtie S))$
- ■ $\delta(\pi_A(R)) \equiv \pi_A(R)$
- ■ $\delta(\pi_A(R \bowtie S)) \equiv \pi_A(R \bowtie S)$
- ☐ $\pi_A(R \bowtie S) \equiv \pi_A(R)$

Part 1.3 Index Structures (Total: 30 Points)

Assume that you have the following table:

Item

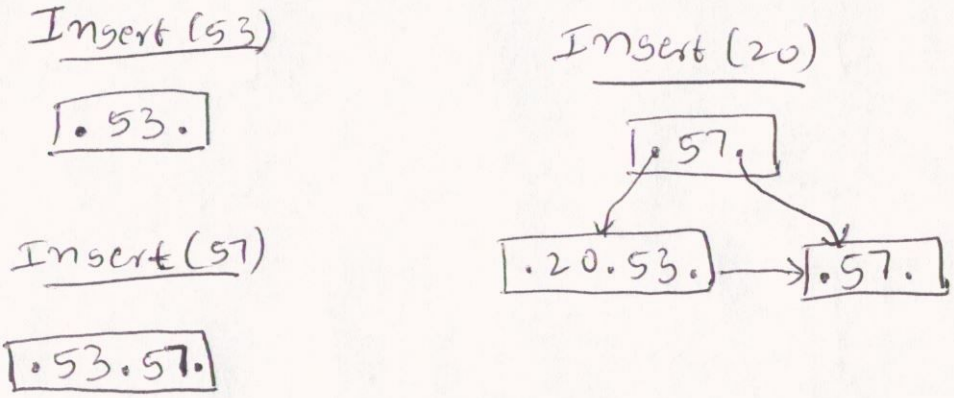
SSN	name	age
1	Pete	53
2	Bob	57
44	John	20
43	Joe	18
45	Alice	19
42	Lily	99
88	Gertrud	60
89	Heinz	14

Question 1.3.1 Construction (12 Points)

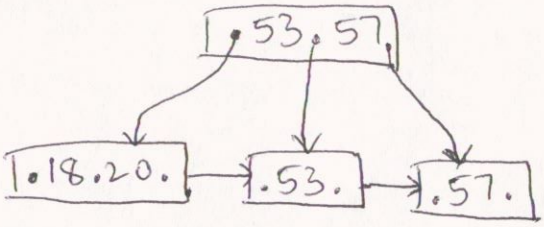
Create a B+-tree for table *Item* on key *age* with $n = 2$ (up to two keys per node). You should start with an empty B+-tree and insert the keys in the order shown in the table above. Write down the resulting B+-tree after each step.

When splitting or merging nodes follow these conventions:

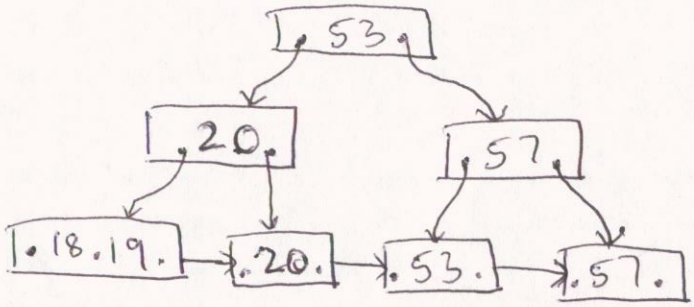
- **Leaf Split**: In case a leaf node needs to be split during insertion and n is even, the left node should get the extra key. E.g, if $n = 2$ and we insert a key 4 into a node [1,5], then the resulting nodes should be [1,4] and [5]. For odd values of n we can always evenly split the keys between the two nodes. In both cases the value inserted into the parent is the smallest value of the right node.
- **Non-Leaf Split**: In case a non-leaf node needs to be split and n is odd, we cannot split the node evenly (one of the new nodes will have one more key). In this case the "middle" value inserted into the parent should be taken from the right node. E.g., if $n = 3$ and we have to split a non-leaf node [1,3,4,5], the resulting nodes would be [1,3] and [5]. The value inserted into the parent would be 4.
- **Node Underflow**: In case of a node underflow you should first try to redistribute values from a sibling and only if this fails merge the node with one of its siblings. Both approaches should prefer the left sibling. E.g., if we can borrow values from both the left and right sibling, you should borrow from the left one.



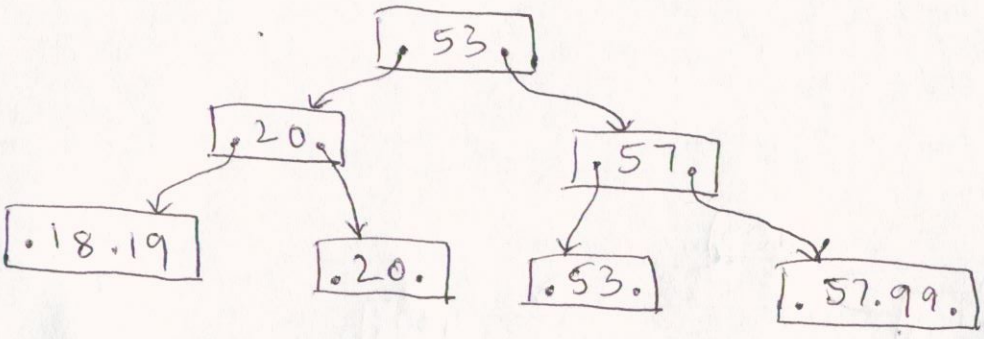
Insert (18)



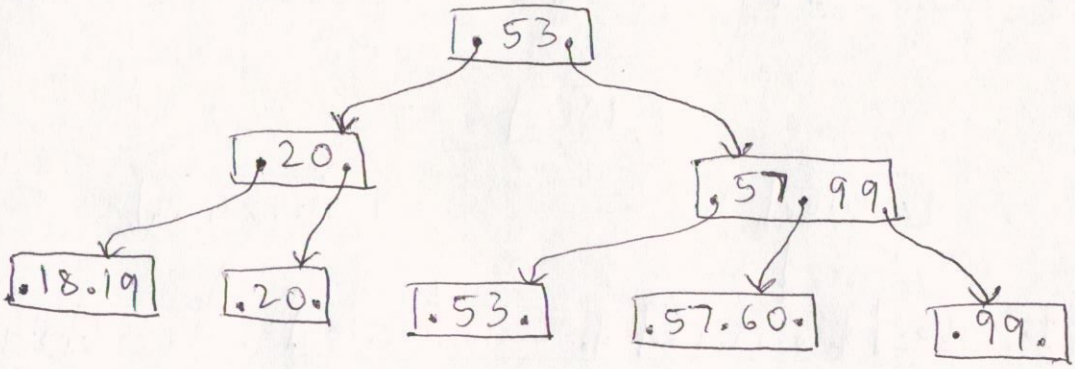
Insert (19)



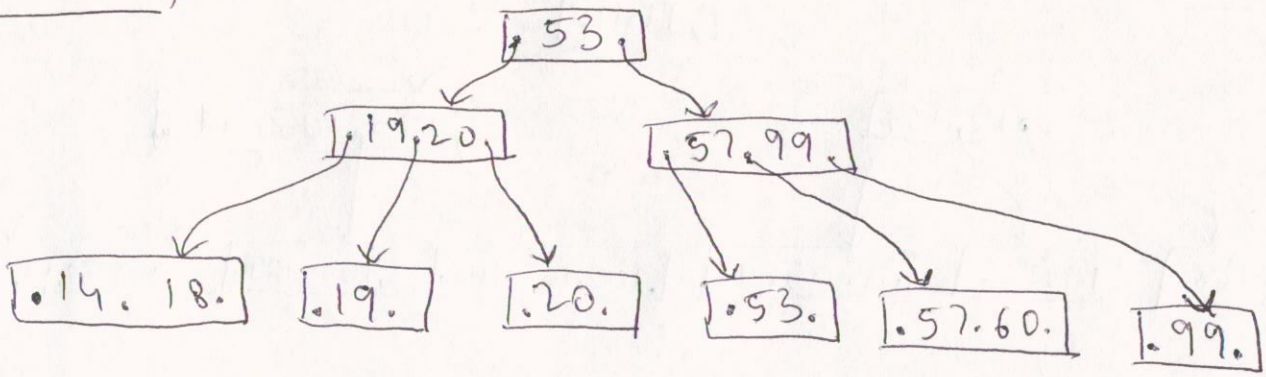
Insert (99)



Insert (60)



Insert (14)

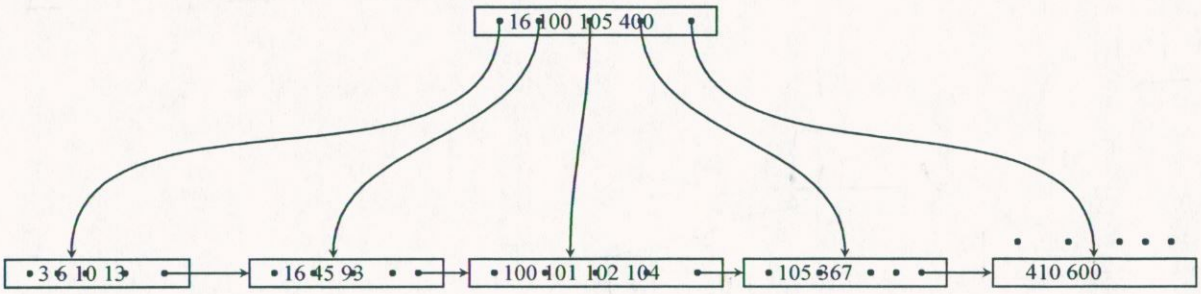


Question 1.3.2 Operations (10 Points)

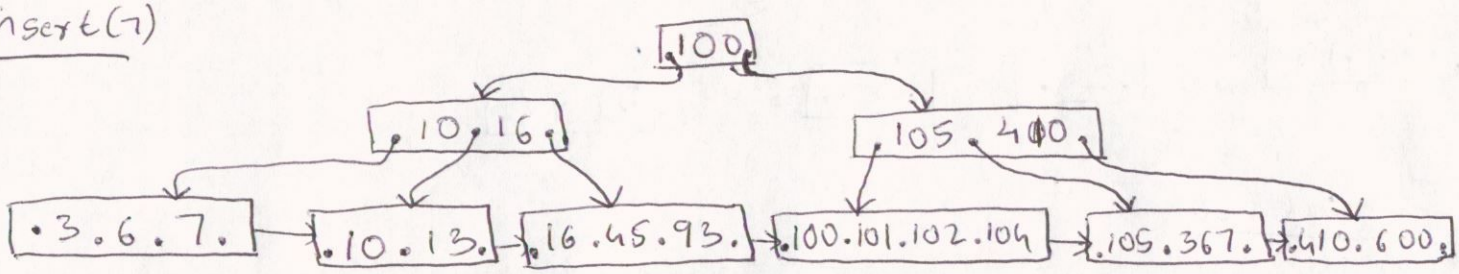
Given is the B+-tree shown below ($n = 4$). Execute the following operations and write down the resulting B+-tree after each operation:

insert(7), insert(8), insert(103), delete(105), delete(410), insert(1)

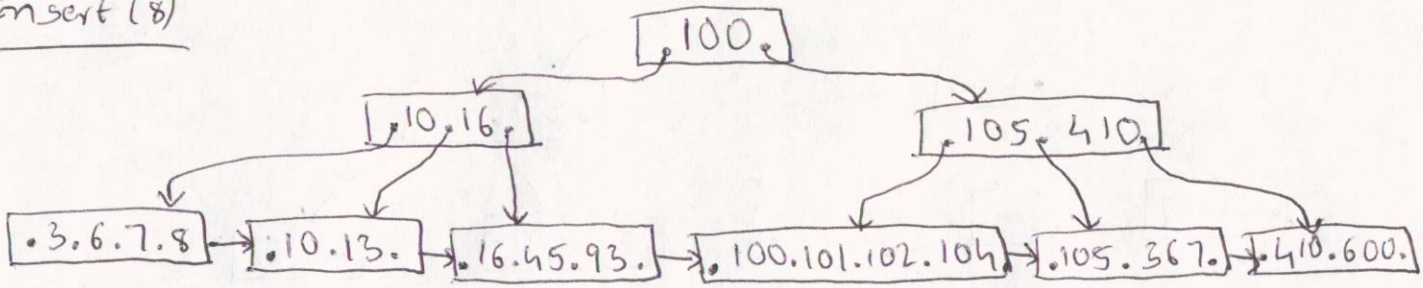
Use the conventions for splitting and merging introduced in the previous question.



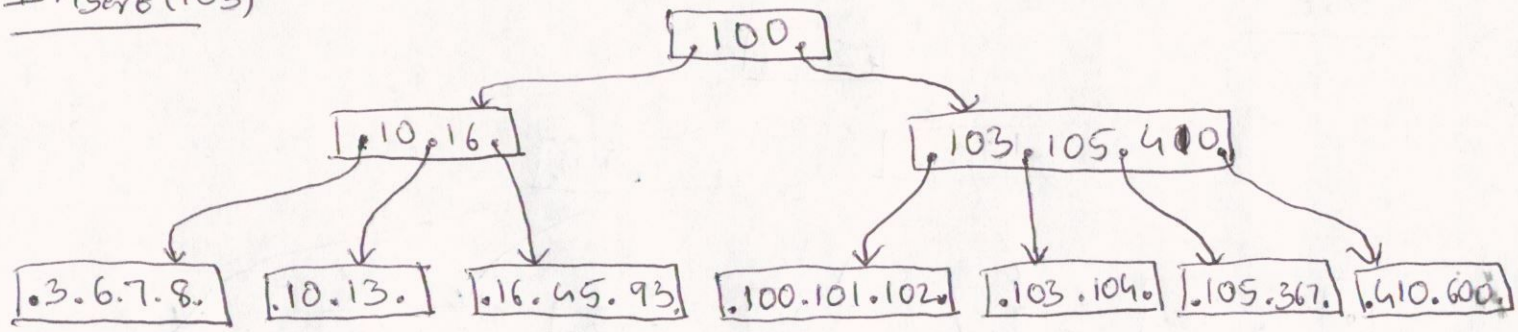
Insert(7)



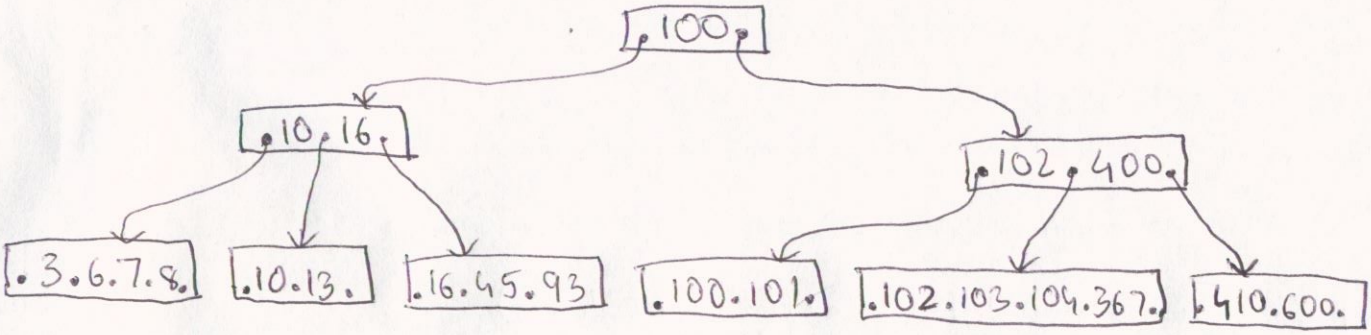
Insert (8)



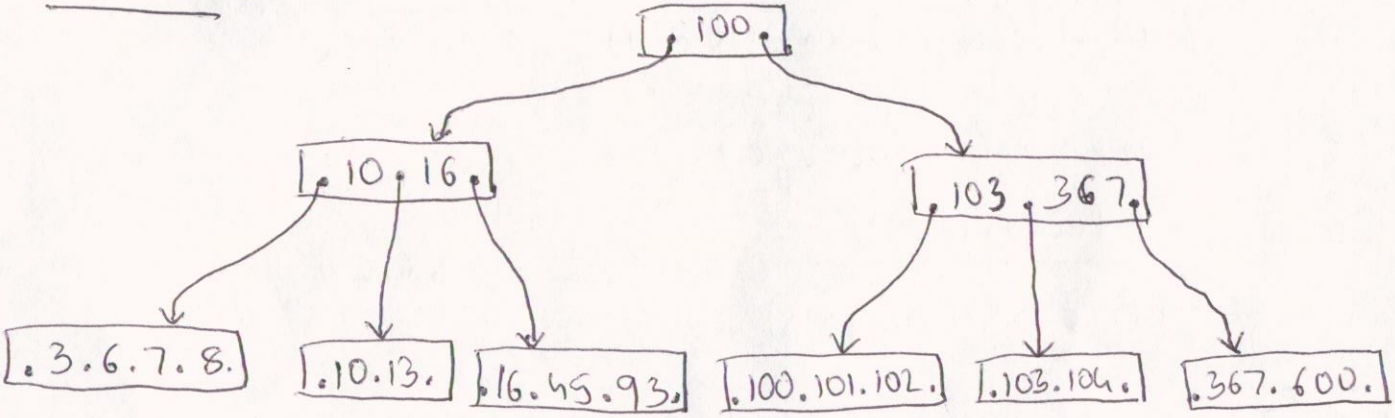
Insert (103)



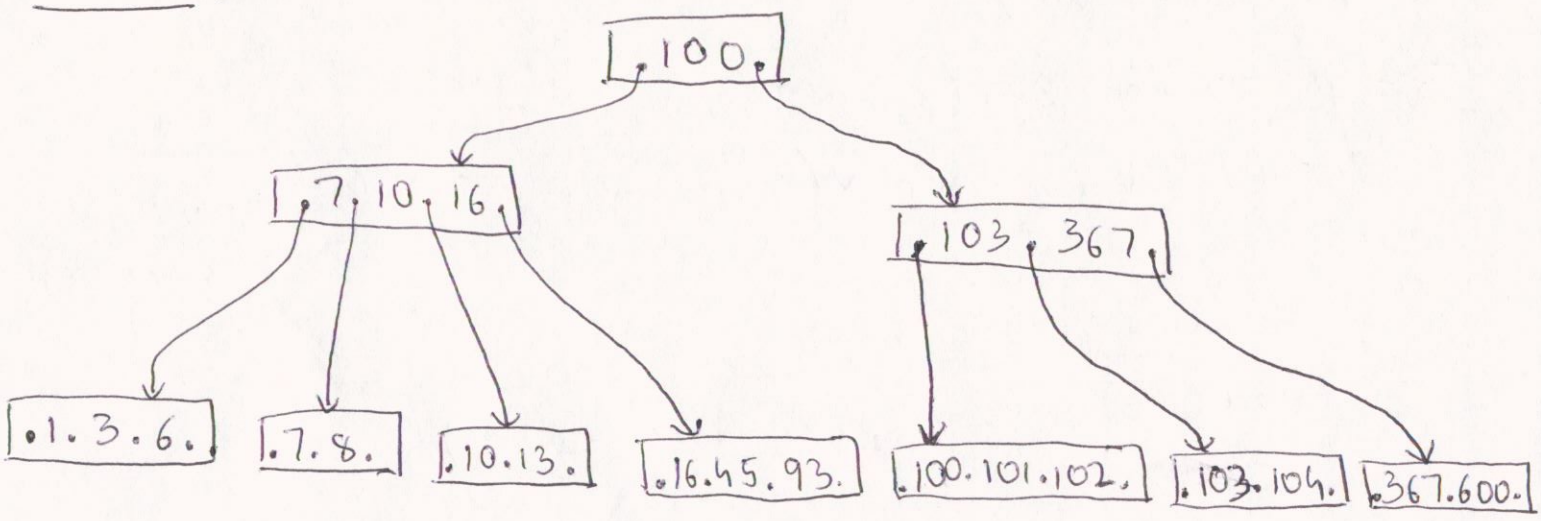
Delete (105)



Delete (410)



Insert (1)



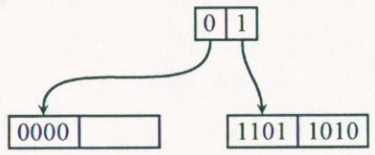
Question 1.3.3 Extensible Hashing (8 Points)

Consider the extensible Hash index shown below that is the result of inserting values **0**, **1**, and **2**. Each page holds two keys. Execute the following operations

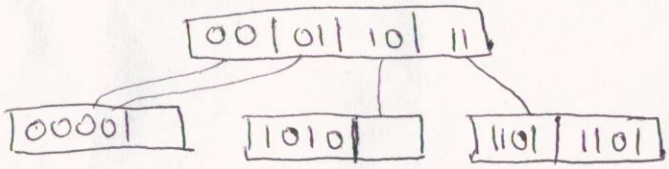
insert(0),insert(5),insert(8),insert(6)

and write down the resulting index after each operation. Assume the hash function is defined as:

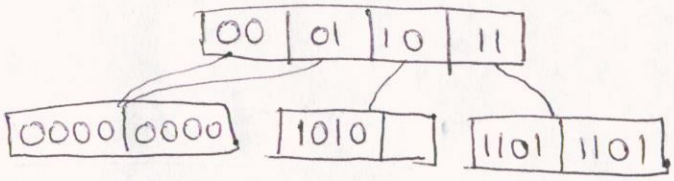
x	h(x)
0	1101
1	0000
2	1010
3	1100
4	0001
5	0000
6	1010
7	0111
8	1110



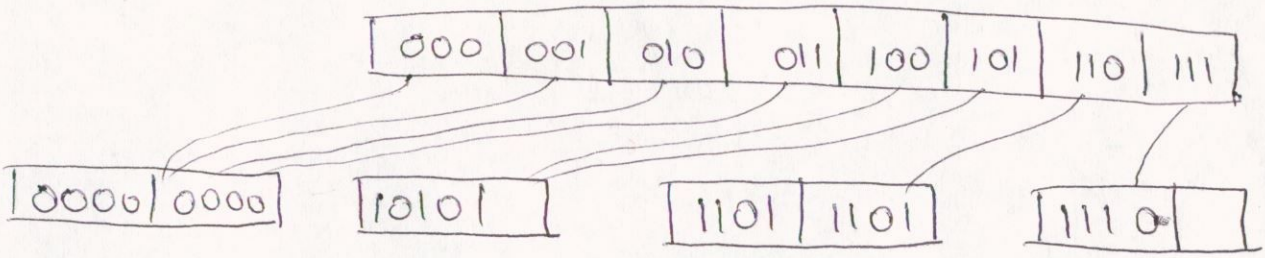
Insert (0) = 1101



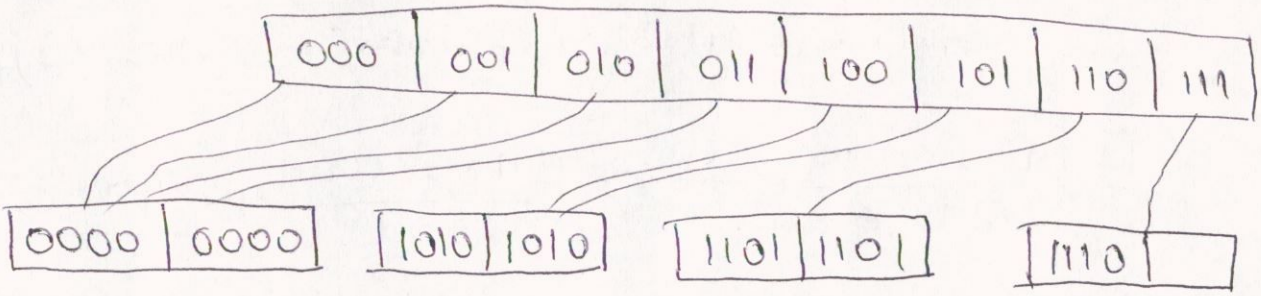
Insert (5) → 0000



Insert (8) → 1110



Insert (6) → 1010



Part 1.4 Result Size Estimations (Total: 10 Points)

Consider a table lecture with attributes title, campus, topic, roomSize, a table student with name, major, age, and a table attendsLecture with attributes student, lecture, and hoursAttended. attendsLecture.student is a foreign key to student. Attribute lecture of relation attendsService is a foreign key to of relation lecture. Given are the following statistics:

T(*lecture*) = **200**	T(*student*) = **30, 000**	T(*attendsLecture*) = **600, 000**
V(*lecture, title*) = **200**	V(*student, name*) = **30, 000**	V(*attendsLecture, student*) = **25, 000**
V(*lecture, campus*) = **3**	V(*student, major*) = **10**	V(*attendsLecture, lecture*) = **150**
V(*lecture, topic*) = **10**	V(*student, age*) = **30**	V(*attendsLecture, hoursAttended*) = **300**
V(*lecture, roomSize*) = **20**		

Question 1.4.1 Estimate Result Size (3 Points)

Estimate the number of result tuples for the query $q = \sigma_{topic=DB}(lecture)$ using the first assumption presented in class (values used in queries are uniformly distributed within the active domain).

$$T_q = \frac{T(lecture)}{V(lecture, topic)} = \frac{200}{10} \Rightarrow \boxed{20}$$

Question 1.4.2 Estimate Result Size (3 Points)

Estimate the number of result tuples for the query $q = \sigma_{hoursAttended>250}(attendsLecture)$ using the first assumption presented in class. The minimum and maximum values of attribute *hoursAttended* are **0** and **299**.

$$T_q = \frac{\max(\text{hours Attended}) - 250) \times T(\text{student})}{\max(\text{hours Attended}) - \min(\text{hours Attended}) + 1}$$

$$= \frac{(299 - 250) \times 30000}{299 - 0 + 1} \Rightarrow \frac{49 \times 30000}{300} \Rightarrow \underline{4900}$$

Question 1.4.3 Estimate Result Size (4 Points)

Estimate the number of result tuples for the query q below using the first assumption presented in class.

$q = (student \cdot a_{name=student}\, \sigma_{hoursAttended \geq 0}(attendsLecture)) \cdot a_{lecture=title}\, \sigma_{campus=Mies}(lecture)$

$q_1 = \sigma_{hoursAttended \neq 0}(attendsLecture)$

$T_{q_1} = \frac{T(attendsLecture)}{V(attendLecture, hoursattended)} = \frac{600000}{300} = 2000$

$q_2 = \sigma_{campus=Mies}(lecture)$

$T_{q_2} = \frac{T(lecture)}{V(lecture, campus)} = \frac{200}{3} = 66.67$

$V(q_1, student) = 25000$

$V(q_1, lecture) = 150$

$V(q_2, title) = 200$

$T_q = \frac{T(student) \times T(q_1) \times T(q_2)}{\max(V(student, name), V(q_1, student)) \times \max(V(q_1, lecture), V(q_2, title))}$

$= \frac{30000 \times 2000 \times 66.67}{\max(30,000, 25000) \times \max(150, 200)}$

$= \frac{30000 \times 2000 \times 66.67}{30000 \times 200} = 666.7$