CSE 344 Midterm Exam

Friday July 21, 2017

Name: _____ Student Number: _____

Problem	Points
1	36
2	20
3	28
4	16
Total	100

- **Do not open** the test until instructed to do so.
- Please read all instructions carefully. You may ask the instructor clarifying questions during the exam.
- This is a closed book exam, but you are allowed one (double sided) page of notes.
- Please silence all cell phones and place them off the table.
- There are 4 questions each with multiple parts. If you get stuck on a question move on and come back to it later. Partial solutions will be graded for partial credit.
- You have 60 min to work on this exam.
- If you need, scratch paper is provided at the front of the room. Good Luck!

This exam uses relations from a database that a gym company uses to track membership and usage between multiple gyms in many different cities. The relations in this database are:

Gym (gid, name, city)
Member (mid , name , is_student, birthdate, city)
Visits (timestamp, mid, gid)

The underlined attributes are primary keys for each relation. The attributes *mid* and *gid* in Visits reference the keys in Member and Gym. Some assumptions you can make about the table are:

- Max length of Member.name and Member.city is 50 characters.
- Member.is_student is a Boolean field (not an Int that can be 0 or 1).
- Member.birthdate is a Date field.
- Visit.timestamp is a Datetime field with the timestamp of the visit.

Question 1: SQL Statements (36 Points)

Part A: Schema Creation (10 Points)

a) Write the SQL Create statement for Member and Visits.

```
DROP TABLE IF EXISTS Member;
CREATE TABLE Member (
      mid INT PRIMARY KEY,
      name VARCHAR(50),
      is_student BOOLEAN,
      birthdate DATE,
      city VARCHAR(50)
);

DROP TABLE IF EXISTS VisIts;
CREATE TABLE Visits (
      timestamp DATETIME,
      mid INT REFERENCES Member(mid),
      gid INT REFERENCES Gym(gid),
      PRIMARY KEY (timestamp,mid)
);
```

Part B: Queries (26 Points)

Each item below describes a query to perform on the database using the schema from the previous page. Provide an SQL statement for each query. For reference we provide the SQLite date functions:

```
date(timesamp/date) => "YYYY-MM-DD"
date('now') => "2017-07-21"  (current date)
year(timestamp/date) => "YYYY"
```

The following SQL would find all gym visits that occurred in 2017 or on July 4, 2016:

```
SELECT * from Visits where date(timestamp) = "2016-07-04" OR
year(timestamp) = "2017";
```

a) Find members who have attended two different gyms on the same day. Return only unique member ids in any order. (10 points)

```
SELECT DISTINCT M.mid
FROM Member M , Visit V1 , Visit V2
WHERE M.mid = V1.mid AND M.mid = V2.mid
  AND date(V1.timestamp) = date(V2.timestamp) -- same day
  AND V1.gid != V2.gid; -- different gyms
```

b) Find non-student members who have visited the gym less than 10 times (all gym visits). For each member return their name, number of times they visited a gym and first date they visited the gym (3 attributes). Include members who have never visit a gym. Order by decreasing visit count (high → low) and then by increasing name (A → Z). (10 points)

```
SELECT DISTINCT M.name , count(*), date(min(V.timestamp))
FROM Members M LEFT OUTER JOIN Visits V ON M.mid = V.mid
WHERE M.is_student = FALSE
GROUP BY M.mid , M.name
HAVING count(*) < 10
ORDER BY count(*) DESC , M.name;
```

c) Indicate which of the following queries correctly finds all members who did not visit any gyms outside of their city: (All queries are syntactically correct). (6 points)

Q1:
```
SELECT DISTINCT M.mid FROM Member M
WHERE NOT EXISTS (
      SELECT * FROM Visits V, Gym G
      WHERE V.mid = M.mid AND V.gid = G.gid
        AND G.city <> M.city
);
```

Q2:
```
SELECT DISTINCT M.mid FROM Member M,  Visits V
WHERE M.mid = V.mid
AND NOT EXISTS (
      SELECT * from Gym G
      WHERE V.gid = G.gid AND G.city <> M.city
); -- Returns mid of anyone who visits a gym not in their
city at least once.
```

Q3:
```
SELECT DISTINCT M.mid
FROM Member M
 LEFT OUTER JOIN Visits V ON M.mid = V.mid
 LEFT OUTER JOIN Gym G ON V.gid = G.gid AND M.city <>
G.city
GROUP BY M.mid
HAVING count(*) = 0; -- count(*) always returns at least 1
so this query will always return 0 tuples.
```

Q4:
```
SELECT DISTINCT M.mid
FROM Member M
 LEFT OUTER JOIN Visits V ON M.mid = V.mid
 LEFT OUTER JOIN Gym G ON V.gid = G.gid AND M.city <>
G.city
GROUP BY M.mid
HAVING count(G.gid) = 0;
```

Answer with any subset of Q1, Q2, Q3, Q4: Q1, Q4

Question 2: Cost Estimation and Indexes (20 Points)

The following database statistics exist for the Member Table

T(Member) = 500	V(Member,city) = 10
B(Member) = 100	V(Member,is_student) = 2

Reminder: The number of tuples returned by $\sigma_{a=?}(R)$ is equal to T(R)* 1/V(R,a)

Part A: Indexes (10 Points)

Consider the following simple SFW query:

```
SELECT name FROM Member
WHERE city = "Seattle WA" AND is_student = True;
```

Estimate cost in disk I/Os of the query in the following conditions (assume all indexes are used):

a) There is no Index

Cost = B(Member) = 100

b) There is an unclustered index Member(city)

Cost = T(Member) * 1/V(Member,city) = 500 * 1/10 = 50

c) There is a clustered index Member(city)

Cost = B(Member) * 1/V(Member,city) = 100 * 1/10 = 10

d) There is an unclustered index Member(is_student)

Cost = T(Member) * 1/V(Member,is_student) = 500 * 1/2 = 250

e) There is an unclustered index Member(city,is_student)

Cost = T(Member) * 1/V(Member,city) * 1/V(Member,is_student) = 500 * 1/10 * 1/2
= 25

Part B: Joins (10 Points)

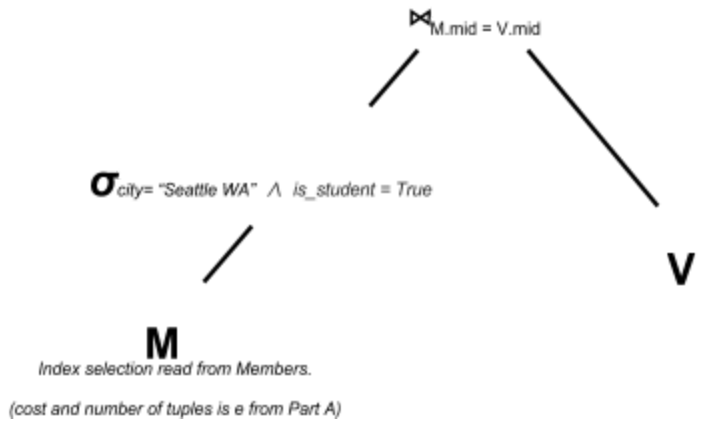
We now want to count how many times students in Seattle went to a gym with this query:

```
SELECT name, count(*) FROM Member M, Visits V
WHERE M.mid = V.mid AND city = "Seattle WA" AND is_student =
True
GROUP BY name;
```

The Relation Algebra for this join statement is below. However, multiple types of join algorithms can be used. Estimate the cost for a nested loop join with and without an index on Visits(mid). In both cases the Members table will be scanned using the Member(City,is_student) index from the previous question. No temporary tables are written to disk. The cost of reading M is therefore your answer from e in Part A - if part e was wrong you will not lose points again here.

B(Visits) = 400
T(Visits) = 5000

V(Visits,mid) = 500



a) What is the cost of a Nested Loop join with V

The cost of reading M, plus for each tuple selected from M the cost of reading V. This assumes that less than B(Member) tuples are selected from M

Cost = Part_A.f + Part_A.f * B(Visits)
= 25 + 25 * 400
= 10025

b) What is the cost of a Nested Loop join with Visits using an unclustered index Visits(mid)

The cost of reading M, plus for each tuple selected from M the cost of selecting that mid from Visits.

Cost = Part_A.f + Part_A.f * T(Visits) * 1/V(Visit,mid)
= 25 + 25 * 5000 * 1/500
= 275

Question 3: Relational Calculus and Datalog (28 Points)

For this section we will use these simplified versions of the gym relations:

```
Member(mid,name,city)
Visits(ts,mid,gid)
Gym(gid,city)
```

Part A: Relational Calculus (8 Points)

State in English what each of the following relational calculus queries return:

a) $P(x) = \exists a.\exists b.\exists g.\exists c.(\text{Member}(x,a,c) \wedge \text{Visits}(b,x,g) \wedge \text{Gym}(g,c))$

Members who have visited a gym in their city.

b) $P(x) = \exists a.\exists c.\ \text{Member}(x,a,c) \wedge (\forall g.(\text{Gym}(g,c) \Rightarrow \exists b.\ \text{Visits}(b,x,g)))$

Members who visited all gyms in their city.

Part B: Datalog (10 Points)

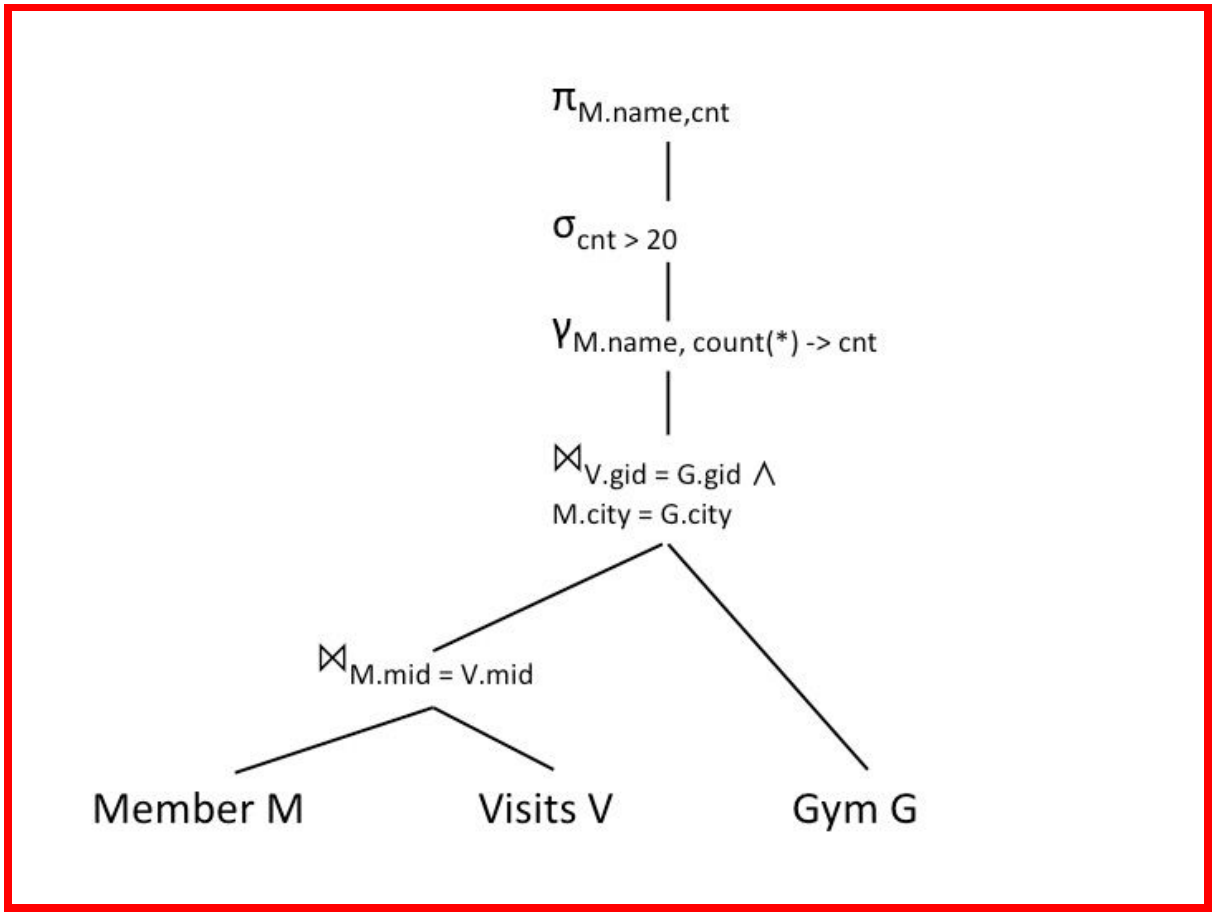
a) Write a Datalog program that finds the names of member pairs who only visit gyms on the same day. (Note: this can be any gym but must be the same day). Assume that the function Date(ts) returns "YYYY-MM-DD".

NotSameDay(x,y) := Visit(ts1,x, _) , Visits(ts2,y,_) , Date(ts1) != Date(ts2)
Ans(m,n) := Member(x,m,_) , Member(y,n,_) , not NotSameDay(x,y) , x != y

Part C: Relational Algebra (10 Points)

a) Write a Relational Algebra expression in the form of a logical query plan (i.e., draw a tree) that is equivalent to the query below. Your plan does not have to be "optimal": however, points will be taken off for overly complex solutions.

```
SELECT M.name, count(*) AS cnt
FROM Member M, Visits V, Gym G
WHERE M.mid = V.mid AND G.gid = V.gid
 AND G.city = M.city
GROUP BY M.name
HAVING count(*) > 20;
```



Question 4:Short Answer (16 Points)

a) You and a friend go to the gym from Question 1. You arrive at the same time and sign in together. However, the following error is raised:

Error: Duplicate entry '1500602520' for key 'PRIMARY'

What did the DBA do wrong when creating the tables to cause this error? How would you fix the table schema?

This looks like a duplicate primary key error meaning that the primary key on the Visits table is incorrect. The primary key is either just the timestamp (meaning two people couldn't visit gyms within at the exact same time) or just the mid (meaning someone couldn't visit gyms more than once). Since `1500602520` is the unix timestamp of when this exam started it's probably on timestamp.

To fix this you would need to alter the table and a multiple attribute primary key on (timestamp, mid) to the Visits table.

b) Signing someone in at the gym is now taking a very long time. You are hired to optimize the database. Inspecting the schema you find many indexes on all the fields, including a clustered index on Visit(mid). Why would this slow down creating a new Visit? What information would you need to decide which indexes to keep and which to remove?

Having many indexes slows down inserting new data into the database because for each addition all affected indexes must be updated. Having a clustered index on Visit(mid) is particularly bad because this would rearrange the order data is stored on disk every time someone visits a gym.

Having some indexes is a good idea, but you only want indexes that will help speed up queries. To select the indexes to use you need to look at 1) which queries are executed and 2) how frequently each query is executed.

c) Describe the difference between a logical query plan and a physical query plan. At what stage of query execution is each used?

A logical query plan is the order that a query executes. It specifies if a selection happens before or after a join or which order tables should be joined. A physical query plan specifics how each operation should be done (e.g. which join algorithm to use or if an Index Scan should be done). Both the logical and physical plans are used during query optimization. Once a final physical plan has been selected it is used to get data off of disk and execute the query.

d) Split the following five query languages into two groups based on expressive power. All languages in each group should have equivalent expressive power. The expressive power of all languages is Group Two should be greater than those in Group One.

```
Relational Algebra (RA)
extended RA
Relational Calculus (RC)
SQL
Datalog¬ (no recursion)
```

Group One	<	Group Two
Relational Algebra		SQL
Relational Calculus		extended RA
Datalog¬ (no recursion)		